AMERICAN SOCIETY

FOR

TESTING MATERIALS.

AFFILIATED WITH THE
INTERNATIONAL SOCIETY FOR TESTING MATERIALS.

PROCEEDINGS

OF THE

SIXTH ANNUAL MEETING,

Held at Delaware Water Gap, Pa.,

July 1, 2, 3, 1903.

VOLUME III.

EDITED BY THE SECRETARY, UNDER THE DIRECTION OF THE COMMITTEE ON PUBLICATIONS.

OFFICE OF THE SECRETARY, UNIVERSITY OF PENNSYLVANIA, PHILADELPHIA, PA.

PUBLISHED BY THE SOCIETY.

1903.

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DELAWARE WATER GAP, PA., JULY 1, 2, 3, 1903.

THE SIXTH ANNUAL MEETING OF THE AMERICAN SOCIETY FOR TESTING MATERIALS was held at the Kittatinny Hotel, Delaware Water Gap, Pa., on July 1, 2, 3, 1903. The total attendance at the meeting, including guests, was upward of one hundred.

The following members were present or represented at the meeting: Ajax Metal Company, represented by G. H. Clamer; American Bridge Company, represented by C. C. Schneider; American Foundrymen's Association, represented by Richard G. G. Moldenke; Bethlehem Steel Company, represented by Albert Ladd Colby; C. W. Boynton, Joseph W. Bramwell, F. A. Burdett; Cambria Steel Company, represented by George E. Thackray; William Campbell; Carnegie Steel Company, represented by John McLeod and E. H. Martin; F. D. Carney, James Christie, F. H. Clark, Albert Ladd Colby, Edgar S. Cook, David S. Creswell, Harold M. Dabbs, H. E. Diller; Dixon Crucible Company, represented by Malcolm McNaughton; W. C. Du Comb, Jr., Charles B. Dudley, W. O. Dunbar; *Engineering Record*, represented by John M. Goodell; J. Walter Esterline; Farrel Foundry and Machine Company, represented by Herbert E. Field; Francis A. J. Fitzgerald, Stanley G. Flagg, Jr., Edward M. Hagar, William K. Hatt, Charles L. Huston; Illinois Steel Company, represented by P. E. Carhart; *Iron Trade Review*, represented by A. I. Findlay; Robert Job, Arthur N. Johnson; Jones and Loughlins, Limited, represented by Jesse J. Shuman; William Kent, J. A. Kinkead, C. Kirchhoff, D. A. Kohr, Gaetano Lanza; Lathbury & Spackman, represented by E. W. Lazell; R. W. Lesley; Lukens Iron and Steel Company, represented by Charles L. Huston;

John McLeod, Charles Major, Edgar Marburg, Charles A. Matcham, John A. Mathews, Richard K. Meade, E. D. Meier, Mansfield Merriman, Rudolph P. Miller, Charles M. Mills, Richard G. G. Moldenke, George L. Norris, Logan Waller Page; Pennsylvania Steel Company, represented by F. D. Carney; James Madison Porter, H. H. Quimby, David Reid, Joseph W. Richards, Clifford Richardson, Joseph Royal, A. H. Sabin, Albert Sauveur, W. G. Scott, Henry B. Seaman, Porter W. Shimer, Jesse J. Shuman, Clinton R. Stewart, E. Platt Stratton, George F. Swain, Howard Taggart, William Purves Taylor, George E. Thackray, George W. Thompson, J. L. Van Ornum, Charles H. Vannier, S. S. Voorhees, Samuel Tobias Wagner, George S. Webster, William R. Webster, J. W. Whitehead, Jr., Jasper Whiting, Max H. Wickhorst, N. B. Wittman, Paul L. Wolfel, Walter Wood, representing also R. D. Wood Company. Total number, 89 (including representations); total number in personal attendance, 82.

FIRST SESSION.—WEDNESDAY, JULY 1, 3 P.M.

Business Meeting.

President Charles B. Dudley in the chair.

The minutes of the Fifth Annual Meeting were approved as printed.

The Annual Report of the Executive Committee was read by the Secretary and adopted.

The following amendments of the By-Laws, proposed by the Executive Committee, were passed to letter-ballot by unanimous vote:

That Section 3, Article I., be designated Section 4, and that a new Section 3 be inserted, viz.: Any member who subscribes annually the sum of fifty dollars ($50) toward the general funds of the Society shall be designated a Contributing Member, his rights and privileges as a member remaining unchanged.

The Chair appointed Messrs. G. H. Clamer and W. K. Hatt as tellers to canvass the ballot for officers.

Then followed the presentation and discussion of the reports of the following committees:

On Preservative Coatings for Iron and Steel. S. S. Voorhees, Chairman.

On the Magnetic Properties of Iron and Steel. J. Walter Esterline, Chairman.

On Standard Specifications for Cast Iron and Finished Castings. Walter Wood, Chairman.

Professor J. L. Van Ornum gave an informal account of his experiments on "The Effect of Repeated Stresses on Concrete," which was followed by a general discussion.

A motion offered by Mr. R. W. Lesley, that the Executive Committee be requested to consider the desirability of appointing a committee on "Reinforced Concrete Construction," with a view of coöperating with other societies in the study of that subject, was adopted.

The tellers reported that 77 legal ballots for officers had been cast, and in accordance with their report the Chair declared the election of Messrs. Albert Ladd Colby and John McLeod as members of the Executive Committee for the ensuing term of two years.

The meeting thereupon adjourned till 8 P.M.

SECOND SESSION.—WEDNESDAY, JULY 1, 8 P.M.

Vice-President R. W. Lesley in the chair.

The session was opened with the reading of the Annual Address by the President on "The Making of Specifications."

Vice-President Lesley then yielded the chair to President Dudley, and Mr. A. Cushman read a paper on "The United States Road Material Laboratory: Its Aims and Methods," by Messrs. L. W. Page and A. Cushman.

On close of the discussion, Mr. L. W. Page moved that the question of appointing a committee on "Specifications for Road Material Tests" be referred to the Executive Committee.

Professor W. K. Hatt suggested the desirability of recommending

to the Executive Committee that this question be referred to the Committee on "Standard Specifications for Paving and Building Brick," whose title might be changed to that proposed by Mr. Page.

Mr. Page accepted this suggestion as an amendment to his motion, and the motion thus amended prevailed.

This was followed by the reading and discussion of a paper on "A Preliminary Program for the Timber Test Work to be Undertaken by the Bureau of Forestry, United States Department of Agriculture," by Professor W. K. Hatt.

The meeting then adjourned till the following morning.

THIRD SESSION.—THURSDAY, JULY 2, 10 A.M.

On Specifications for Iron and Steel.

President Dudley in the chair.

The session was opened with the presentation of the annual report of Committee "A" on Standard Specifications for Iron and Steel, William R. Webster, Chairman.

The following specifications were submitted with introductory remarks on the part of the representatives of the various committees:

By Mr. C. C. Schneider—Specifications for Iron and Steel Structures Adopted by the American Railway Engineering and Maintenance of Way Association in March, 1903. J. P. Snow, Chairman.

By Mr. F. H. Clark—Specifications for Locomotive Axles and Forgings Recommended by a Committee of the American Railway Master Mechanics' Association in June, 1903. F. H. Clark, Chairman.

By Mr. William R. Webster—Specifications on Steel Rails Adopted by the American Railway Engineering and Maintenance of Way Association in March, 1902, and the Modifications Submitted in March, 1903. William R. Webster, Chairman.

By Mr. Albert Ladd Colby—Manufacturers' Standard Specifications as Revised in February, 1903, and Their Comparison with Other Recent Prominent Specifications.

By Mr. William Kent—Specifications for Boiler Plate, Rivet Steel

Steel Castings, and Steel Forgings Recommended by a Committee of the American Society of Mechanical Engineers in June, 1903. H. W. Spangler, Chairman.

After a general discussion, the foregoing specifications were referred to Committee "A" on Standard Specifications for Iron and Steel.

In the absence of the author a paper entitled "A Brief Account of the History and Methods of the International Railway Congress," by Mr. P. H. Dudley, was read by title.

Then followed a topical discussion on the question, "In What Respects Do the Requirements for Structural Steel for Bridge-Building and Ship-Building Purposes Differ?"

On motion this question was referred to Committee A.

The meeting then adjourned till 8 P.M.

FOURTH SESSION.—THURSDAY, JULY 2, 8 P.M.

On Steel.

President Dudley in the chair.

The program was begun with a topical discussion on "The Applications of Nickel Steel," introduced by Messrs. Charles B. Dudley, Albert Ladd Colby, and John McLeod.

A paper on "The Casting of Pipeless Ingots by the Sauveur Overflow Method," by Messrs. Albert Sauveur and Jasper Whiting, was followed by a topical discussion on "The Rolling of Piped Rails," opened by Messrs. Albert Sauveur and Robert Job.

In the absence of the author, Mr. Gustav Lindenthal, a paper on "Alternate Stresses in Bridge Members" was read by title.

On motion of Mr. E. D. Meier, the Executive Committee was requested to consider the desirability of co-operating with other organizations to bring about a modification of the laws governing the inspection of steamboat and steamship boilers.

The meeting then adjourned till the following morning.

FIFTH SESSION.—FRIDAY, JULY 3, 10 A.M.

Section on Cast Iron.

President Dudley in the chair.

A paper on "The Importance of Adopting Standard Sizes of Test Bars for Determining the Strength of Cast Iron," by Mr. Alex. E. Outerbridge, Jr., was, in the absence of the author, read by title.

The following papers were then presented in the order given and discussed jointly:

"Machine-Cast Sandless Pig Iron in Relation to the Standardizing of Pig Iron for Foundry Purposes," by Mr. Edgar S. Cook.

"The Physical Properties of Malleable Castings as Influenced by the Process of Manufacture," by Mr. Richard Moldenke.

"Cast Iron for Dynamo and Motor Frames," by Mr. H. E. Diller.

"A Consideration of the Reactions that Make Cast Iron Valuable," by Mr. H. E. Field.

Then followed a discussion of the paper on "The Constitution of Cast Iron," presented by Professor Henry M. Howe at the Fifth Annual Meeting. This discussion was opened by Messrs. William Campbell and Albert Sauveur.

A paper on "The Demand for a Specified Grade of Cast Iron," by Mr. W. G. Scott, was read by title.

An adjournment was then taken till 3 P.M.

Section on Cement and Bitumen.

Vice-President R. W. Lesley in the chair.

The report of the Committee on Standard Specifications for Cement was presented by Professor George F. Swain, Chairman.

Mr. Clifford Richardson stated that it had been found impracticable to effect a satisfactory organization of the Committee on Bitumen and recommended that this committee be discharged. On motion it was recommended that the Executive Committee take such action.

The following papers were then read and discussed:

"The Testing of Bitumens for Paving Purposes," by Mr. A. W. Dow.

"Portland Cement Mortar Exposed to Cold," by Mr. C. S. Gowen.

"Some Observations on the Effect of Water and Combinations of Sand upon the Setting Properties and Tensile Strength of Portland and Natural Cements," by Mr. E. S. Larned.

"Soundness Tests of Portland Cement," by Mr. W. P. Taylor.

A paper on "Tests on the Compressive Strength of Concrete and Mortar Cubes," by Mr. C. H. Umstead, was read by title.

The meeting then adjourned till 3 P.M.

SIXTH SESSION.—FRIDAY, JULY 3, 3 P.M.

President Dudley in the chair.

In the absence of the authors the following papers were read by title:

"Springs," by Mr. William Metcalf.

"The Master Car Builders' Drop-Testing Machine as Installed at Purdue University," by Professor W. F. M. Goss.

"Stremmatograph Tests of Unit Fiber Strains and Their Distribution in the Base of Rails under Moving Locomotives, Cars, and Trains," by Mr. P. H. Dudley.

Then followed the reading and discussing of the following papers:

"The Control of the Finishing Temperatures of Steel Rails by the Thermo-Magnetic Selector," by Messrs. Albert Sauveur and Jasper Whiting.

"A Direct-Reading Apparatus for Determining the Energy Losses in Transformer Iron," by Professor J. Walter Esterline.

"The Strength and Other Properties of the Light Aluminium Alloys," by Professor J. W. Richards.

"The Testing of Bearing Metals," by Mr. G. W. Clamer.

On motion of Professor G. Lanza, the question as to what, if anything, should be done by way of studying the behavior of material subjected to alternate stresses, was referred to the Executive Committee, with power.

The following resolutions offered on behalf of the Executive Committee were adopted: First, that on all standing committees concerned with subjects involving commercial interests an equal numeric balance shall be preserved between engineers, scientists, and representatives of consumers on the one hand, and manufacturers or their representatives on the other; second, that the permanent chairmanship shall be vested in a member belonging to the former class, duly elected by the Committee.

The President thereupon declared the meeting adjourned *sine die*.

American Society for Testing Materials.

AFFILIATED WITH THE
INTERNATIONAL SOCIETY FOR TESTING MATERIALS.

PROCEEDINGS.

THE MAKING OF SPECIFICATIONS FOR MATERIALS.

Annual Address by the President, Charles B. Dudley.

It has occurred to us that in the present state of development of our Society, it might not be amiss to discuss some points in the making of specifications for materials. If we understand the matter correctly, there is more or less doubt and ambiguity in the mind of many; and while it is not hoped or expected that the present discussion will put the whole matter at rest, it is believed that it will serve some valuable purpose to have on record an attempt at a presentation of the case, as it looks to one who has spent over twenty years in daily contact with practical specifications for materials. It is not expected that all that is said will be agreed to, and it is more than probable that much of what follows will be found not applicable by others. Nevertheless, it is perhaps worth our time to go over the matter together.

The first point which we will discuss is the query, "What has a society devoted to the testing of materials to do with the making of specifications?" Should not methods of testing and the finding out of the various properties of materials, which render them valuable and useful, be its legitimate field of study, rather than the assembling or combining of these various properties in the form of specifications? Should not the work of making specifications

be undertaken by the engineers or the parties interested in any case? If we understand the matter rightly, this is the view taken by many of the leaders of the International Association, with which we are affiliated. The properties of materials and the methods of testing to discover those properties, seem to them to be the more legitimate field for the activity of the Society. In this country, on the contrary, we have taken what may be called the "broader view." We regard as our legitimate field of study not only the valuable properties of materials, and the methods by which we are to determine those properties, but also the assembling, into concrete or useful form, our knowledge in regard to any serviceable material. In our view, the more comprehensive field has much to recommend it. While it must be conceded that a society is doing good and valuable work which busies itself with the characteristics of the materials of construction and with the methods of testing, yet we cannot but feel that it must likewise be conceded that a society is doing better work which not only occupies the field of testing and study of materials, but also goes a step farther, and puts its accumulated information with its recommendations into definite and serviceable shape. Much may be said on both sides of the question, and its exhaustive treatment would absorb our whole time. We will therefore only add that we have failed to think of an argument in favor of making methods of testing the legitimate work of such a society as ours, which does not equally justify the making of specifications for materials a part of that legitimate work.

Coming now to the more definite discussion of our theme, it has occurred to us that it might be useful and valuable to give an *exposé* somewhat in detail of the methods practised at Altoona, in connection with the Laboratory of the Pennsylvania Railroad, in making specifications. It is of course recognized at the start that every specification is more or less affected by local conditions, and that much may be said which will not have universal application. Furthermore, the opinions which guide us in our work, and the results which we aim to accomplish, may reasonably not be accepted by others, and we have no disposition to think that what we shall say will be the last words on the subject. It may well happen, as time progresses, that much will be said by others

which will modify our present views and present practice, both in this country and abroad.

The general plan which we have at Altoona is as follows: First, we try to find out what we want. Some difficulty arises in the service; some parts of constructions fail, or some material at present in use does not give satisfactory results, and an investigation is made to see if the cause of the difficulty can be located; or some product which is being largely used and which is being furnished by different makers, is believed not to be of equal quality from the different sources; or, indeed, it is desired to standardize a practice and make it uniform all over the road, and as an element in this problem the same quality of material must be furnished and used. These and other elements lead us to make investigations into the nature of the commercial products involved. These investigations lead to specifications. The specifications, after being made, are placed in the hands of the purchasing agent, and by him are made a part of the contract on which the materials are bought. Shipments of material in accordance with this contract being received, each shipment, or specified definite amount, is sampled, and the samples examined in accordance with the specifications. If the samples stand test, the material is accepted and paid for; if not, the material is rejected and returned to the makers. This plan has been in daily use at Altoona, in connection with the Pennsylvania Railroad, for something over twenty years. The present number of specifications, both physical and chemical, is forty-seven (47).

Now, how shall a specification be made? It is quite obvious from the nature of the case, that primarily in a specification two parties are interested, the producer of the material and the buyer or consumer, and in our first specifications only the relation of these two parties was considered. Indeed, we were accustomed to say for quite a period of time, that a specification was an attempt on the part of the consumer to tell the producer what he wanted. It necessarily followed from this limitation, that the first specifications did little more than define the qualities of the material, and it seems more than probable that general specifications, such as our Society can deal with, will necessarily be largely confined to this feature, namely, defining the quality of the material. It

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is true that methods of sampling, how much material one sample shall represent, and in some cases methods of testing, either in whole or in part, may wisely be embodied in a general specification, but it is obvious that all those features of a specification, which have to do with local conditions, cannot well be made a part of a general specification.

As has already been said, at first our specifications considered almost exclusively the two principal parties involved, namely, the producer and the consumer, but as time progressed it was found desirable and advantageous to consider several other parties, who were or might be involved in the matter. Questions began to arise as to how much material should be involved in one test. Then came the question, Would it not be advisable to buy in lots of the same size as the test involves? Then came the question of sampling. Then came the question, Shall part of the work of deciding whether shipments fill the requirements be done at the works where the material is made, or shall it all be done after the shipment is received? If the former, an inspector is involved, and he must have information which could perhaps best be embodied in the specification itself. Furthermore, those who actually applied the tests, the chemist and the engineer of tests, would frequently ask questions in regard to methods, or interpretation of various points, and finally it was found that those who ultimately receive the material, such as the storekeeper or shop foreman, could frequently make certain inspections, better perhaps and cheaper than anyone else, and so information must be furnished for them. This necessity for information for the use of a number of different parties has made the modern fairly workable specification for certain materials to be a somewhat lengthy and at times a seemingly cumbrous affair. It is difficult to draw the line as to exactly what should be included and what excluded in a specification. The commercial interests of the manufacturer on one side, and the zeal, sometimes excessive it must be confessed, on the other side, on the part of the inspector or chemist or engineer of tests, lead to very close scrutiny of the wording of the specification, and it cannot be denied that many times conditions arise which make those who are deciding the fate of shipments wish that the specifications had been more minutely drawn. In

drawing a specification, one is always between two fires, the fear of making a specification too cumbrous and unwieldy, and the fear of leaving out something which will be found desirable or even essential a little later. As far as we can be said to have reached a positive conclusion at Altoona, it may perhaps be embodied in this, that a good workable specification should contain such information as is needed by the purchasing agent, such information as is needed by the manufacturer, by the inspector, by the chemist, by the engineer of tests, and by the people who are to receive and use the material.

This view of the case will undoubtedly be conceded by all, but the exact amount of information covered by the word "needed" is where the difficulty arises. For example, should the specification cover the chemical method involved in the analysis of the material? Should it cover the methods of testing? Should it cover the complete instructions for the inspector, meeting every point, and so on? Upon this point our views are that the specification should not attempt so much. Where methods of analysis, or methods of testing, or points which the inspector must look out for, are well known, or can be covered in general language, it is sufficient to do this only. Where new methods are involved, which are not well known and recognized, it is essential to either embody these in the specification, or to furnish this information in separate form, and refer to it in the specification. This is common practice, as is well known, in referring to drawings, blue prints, etc., and it may not be amiss at this point to state that in view of the difficulties connected with discrepancies in chemical analyses, we began, several years ago, to print and issue in separate form the methods used in our laboratory, making these methods a part of the specifications by reference only, and thus also a part of the contract. The same practice has prevailed otherwheres in regard to methods of physical testing, and it is our sincere hope that, sooner or later, our Society will issue in printed form what it recognizes as standard methods of testing. Such work, well and carefully done, will relieve specifications of much which they must now necessarily contain.

This, perhaps, is the place to discuss one or two faults characteristic of many specifications which we have seen. We will

not attempt to deny, that in our earlier work on this subject the same faults characterized our specifications. They are in print and may be read and known by all. The special fault which characterizes many specifications is the attempt on the part of the one who draws the specification to make it a place to show how much he knows. We have seen specifications which were apparently drawn with no other thought in mind than to embody all the knowledge the writer had on the subject. No discussion is needed on this point. The folly of it is apparent to all.

Another fault is in putting too many restrictions into the specifications. According to our views, the fewer possible restrictions that a specification can contain, and at the same time afford the necessary protection in regard to the quality of the material, the better the specification is. In some of our specifications we have only one test; in others, perhaps half a dozen; the effort, however, being always to have the minimum number which will yield the product that is required.

A third fault in specifications is in making the limits too severe. Some writers who draw specifications apparently put themselves in a position of absolute antagonism to those who are to make the material, and seem to have as a permanent thought in their minds to tie them down to the extreme limit. The maximum that a single test piece shows, the minimum of an objectionable constituent that may be obtained by analysis, the extreme point in elongation that by chance some good and exceptional sample gives, are made to represent the total output of the works. It is, perhaps, needless to say that such extreme figures are the worst possible mistake in making specifications. The success or failure of structures, or of material in service, does not depend on such extreme figures. It is infinitely better to specify a good average material, and get the necessary protection in structures by a more liberal factor of safety in the design, than to insist on such extreme limits, which can only lead to constant friction and demand for concessions at the penalty of delaying the work.

It may be interesting to know something of the routine leading to a complete specification in our work at Altoona. The first step in the process is the accumulation of information. This we obtain from any available sources. Sometimes we get samples from the

service which have given both good results and bad results, a sufficient number being obtained to get a reasonable average, and make of these samples careful analyses and physical tests. If now the results obtained show a difference, either in physical properties or in chemical composition between the good and the bad, the process is simple. The qualities of the material have actually been decided by the service. Again, in certain specifications the service does not give so much information, or it takes years for the service to develop what is good and what is bad. In such cases general knowledge is made use of, the resulting specifications being regarded as tentative, and after the material begins to be received it is carefully watched to see how it behaves. Again, direct, positive experiments are made, sometimes on a fairly large scale. The experiments leading up to the thermal test for cast-iron wheels involved the testing of some 200 wheels, representing as many kinds of wheels as could be obtained. These wheels were all tested thermally, and a complete record made of their behavior. By far the largest portion of them were then likewise analyzed, to see whether chemistry would throw any light on the problem. In the work leading to the specifications for axles, some two or three years were involved in the accumulation of the information. Every broken axle that failed in service, for a long time, was carefully analyzed and physical tests made. Again, it is of course recognized that the possibilities of the material must be considered; nothing must be specified beyond what the material will reasonably give. Again, in the accumulation of our material leading to a specification, it is usually customary to pay a visit to the parties who make the materials involved, and learn from them, as far as possible, what their materials will give. A more or less intimate knowledge of the methods used in the manufacture of the constituents which enter into the finished product, and of the properties of each, we deem an essential prerequisite to the drawing of a specification. Finally, the experience of practical men, as to the behavior and characteristics of materials which have been used for years, are made use of. Sometimes in writing, and sometimes in personal interview, these men are requested to state their experience, and it is not too much to say that from the practical men who know materials, principally by their daily

contact with them, extremely good and helpful suggestions have often been obtained. It should not be forgotten to mention, also, that other specifications, printed matter of all kinds, of which there is now such an abundance, proceedings of societies for testing, and other learned societies, investigations made and published by engineers, etc., are drawn upon whenever possible. It will be readily understood that this accumulation of information in the case of important specifications takes much time. Some materials have been under study for ten years or more, and no specification has yet resulted. Other subjects are simpler and the specifications can be made in a few weeks. Not a few of our specifications at Altoona represent two or three years' work in the accumulation of information, before it is ever put in shape.

The material having been accumulated is digested, and some one of us puts it into the form of a specification, and here I may say what has been mentioned before, that it is rare that any attempt is made to put into the first draft of a specification all the knowledge that we have. In the thermal test of wheels already referred to, it was found that wheels under thermal test broke in nine different ways, and that they stood under thermal test without breaking from a few seconds to seven minutes. The specification as finally drawn rejected wheels only when they broke in two out of the nine different ways, and required that successful wheels must stand without breaking in those two ways for two minutes. It is a great temptation, and a common error, to put into the first draft of a specification too much. It must be remembered when making a specification for a material which has hitherto not been subjected to test, that the manufacturer is more or less uncertain as to his product, and that it may require on his part changes in methods, and possibly in materials entering into his product, in order to meet the requirements of the specifications. If now too much is put into the first draft, the inevitable result will be that undue difficulties will be introduced in the manufacture, and the consumer will not infrequently find himself without the possibility of supplying his wants in the market. It is infinitely better to make the first draft of a specification embody only a few essential points, and after such changes in the works have been made as enable the manufacturer to meet these requirements, to revise the

specification, embodying more. A not inappropriate illustration of this point may be found in the drop test for car wheels. Although the car wheels made at Altoona many years ago would stand the drop test specified up to fifteen or twenty blows without breaking, the first specification for drop test of car wheels which was put out for public use was limited to three blows of the same drop, and it was with difficulty that wheels were obtained even under this test. In the course of a few months, however, the test was easily met, and was even made more rigid, and ultimately reached a limit of eight blows.

To return now to the specification. As previously stated, the material is put into shape by some one of us at Altoona. Then a conference is called, consisting of the mechanical engineer, the engineer of tests, the chemist, and the general superintendent of motive power, under whose supervision, according to the organization of the Pennsylvania Railroad Company, all tests and experiments are made. Others having special knowledge may be invited to this conference. The specification as drawn is carefully read over and criticised. As the result of this criticism it is redrawn, and then the material is put in print, copies of the print being sent to the purchasing agent, and to each of the superintendents of motive power of the system. Along with the printed copy goes a request to each of the superintendents of motive power to criticise the specification on his own part, and submit it to his master mechanics or to those of his subordinates who may use the material and may be competent to criticise. To the purchasing agent the request is made that he shall submit the specification to all those manufacturers of the material involved from whom he desires to buy, with request for the freest possible criticism from their standpoints. The criticism from the service through the superintendents of motive power many times yields valuable suggestions. The criticisms from the manufacturers have been the result of some very peculiar and interesting episodes. Some of the manufacturers, apparently fearing that their criticisms may affect the placing of orders, content themselves by saying that they can meet the specifications as well as any one, and that they should be glad to have orders in accordance with them. Others take the occasion to bring forward characteristics of their own products. For ex-

ample, in criticising a proposed specification for petroleum products at one time, one manufacturer desired a clause introduced that only Pennsylvania petroleum should be used. At one time in the criticism of a proposed specification for rails, information was developed seeming to indicate that the effect of certain constituents on steel was a question of geography, thus: The manufacturers east of the Susquehanna River brought forth the statement that sulphur and copper were not injurious to steel, but that phosphorus was its bane, while the manufacturers west of Pittsburg brought forth the equally remarkable statement that phosphorus did not do much damage to steel, but that sulphur and copper were most injurious to it. Those who were located between those two points practically said: We will give you whatever you pay for. Some manufacturers, however, in criticising specifications, apparently size up to the situation, and give honest and valuable suggestions.

We regard this submission of a specification to the manufacturers, before it is issued, as a matter of the utmost importance. In the early days our idea was, as already stated, to tell the manufacturers what we wanted. We were the parties to define the material, and it was their part to simply give us what we asked for. At the present time our idea is that the specification should be the embodiment of the best that is known on the subject, no matter where the information comes from, and that it is simply the part of wisdom, and that we are not only foolish but short-sighted and unfair, if we attempt to make a specification without at least giving the manufacturer an opportunity to co-operate. We feel that the specification should be regarded as partly his creation, as well as ours, and that he should be able to see his own handiwork in it. We are free to put on record that to the co-operation and help of the manufacturers of materials quite a portion of the success, if any, that has attended the Pennsylvania Railroad specifications has been due.

The criticisms from all sources having been received, the specification is carefully gone over again in the light of these criticisms. As far as possible the valid and valuable suggestions of all are embodied. Conflicting criticisms, many times due to local conditions, are harmonized as well as may be, and the specification as redrawn and codified is then submitted to the

proper officers for approval, and ultimately issued and made a part of the contract on which materials are furnished, as has already been described.

As already stated, it is not hoped or expected that the processes and methods made use of in the making of specifications by the Pennsylvania Railroad can be followed in minute detail by others in making specifications, and yet there is a single thought upon this phase of the case which seems to us worthy of some careful consideration, namely, the greater the care, the larger the amount of study, and the more well-directed time and effort that are put upon the specification before it is issued, the less will probably be the difficulty connected with it after it has once become a part of the contract. To our minds, the making of successful specifications demands more ability and a higher order of work than has heretofore been commonly given to it. The valuable specification represents the fruition of the studies of those who make investigation into the properties of useful materials, and of those who use them, and in reality it is the culmination of the work of our Society.

So much may be said on this subject, that it would be easy to weary you with it, but I trust you will bear with me while I touch upon one or two points farther. As we understand the matter, there is opposition on the part of the manufacturers of steel to having the consumer put out chemical specifications in detail. It is claimed that the consumer should only specify the physical properties of the metal, and exclude or limit by the chemistry only constituents which are objectionable, leaving the steel-maker free to vary those constituents, upon which the most valuable properties of the steel depend, according to his own ideas. This feeling, if we are rightly informed, is much stronger abroad than it is with us, and we have been told that steel-makers abroad would not bid on a specification of which complete chemical requirements were a part. From what has preceded, it will not be difficult to understand how we feel about this matter, and it is hard for us to conceive where the method outlined above is followed, and especially where the manufacturer has a chance to criticise a specification before it is issued, why there should be any reasonable ground for antagonism to complete chemical speci-

fications. The position which we hold in the matter is that a certain set of physical properties produced by, for example, high carbon and low manganese, may give a steel more valuable to the consumer than approximately the same physical properties, produced by lower carbon and higher manganese, or other interchange of the constituents commonly affecting the physical properties of steel. Moreover, we cannot help feeling that the chance to study the behavior of metal in service, and the relations between its chemical composition and that behavior, is a source of information which should not be ignored. No one can deny that this chance is more open to the consumer than to the producer, and we fail to see why the producer should shut himself out from this source of knowledge. As has already been stated two or three times, in our judgment a good specification is the result of the joint effort both of those who know steel from its behavior while it is being manufactured and of those who know steel from its behavior while in service.

Another point will, perhaps, bear a few words. We have found it difficult in our work to make any definite rule universally applicable, as to how much material should be represented by one sample. Where materials are made in batches or in heats, and the sample is selected at random, no serious difficulty has thus far arisen in making one's sample represent a heat or batch. Where a shipment, as in the manufacture of alloys, may be made up of material resulting from a number of like operations, without any certainty as to uniformity in the output of each complete operation, the question of sampling is more difficult. The same may be said of oils and paints, and other related materials. In such cases, it is usually customary with us to make an arbitrary sampling, and to follow this sampling by occasional more complete sampling, after the material has been received and passed upon. If such more complete sampling shows lack of uniformity in the shipment of material involved, it may not infrequently lead to a modification of the specification.

Closely related to the question of the amount represented by one sample, is how many individual parts shall make up the average sample. For example, shall one ingot represent 20,000 pounds of an alloy, or shall more than one? In a shipment of

oil, shall a sample from one barrel be used, or shall smaller samples from each barrel be mixed to form one average sample? Our practice has been to limit the number of sub-samples entering into the average sample as much as possible, on the ground that the material should be uniform, and that the specification provides wide enough limits to make up for the ordinary variations, where the manufacturing or shop practices are reasonably good. If the material is uniform, or all of it within the limits of the specification, the multiplication of sub-samples really serves no useful purpose, and as we really buy and pay for a material described by the specification, it is not unfair to expect that any and every part of it should be in accordance with that specification.

Another closely related point is the question of re-tests. A shipment of material has been received, sampled in the regular way, and tested, and the material does not stand test. It not infrequently happens that the producer asks for another test, with the hope and expectation that this test will show that the material meets the requirements. No small amount of correspondence and personal interviews have been expended over this matter. Our general position upon this subject has been to decline re-tests, the theory being that the specification was not drawn for the purpose of making it easy for irregular, and we may say possibly carelessly made, material to be accepted. If a second test is made which does meet requirements, it is obvious that the consumer would naturally want to make a third test, and see which one the third test sustained, and we believe many specifications are drawn with such provisions. We cannot but think that this is bad practice, and that it is infinitely better to make the limits of the specification wide enough when they are first drawn, so that they will cover all the uncertainties in manufacture, except carelessness, bad judgment, or an attempt to sell an inferior product at the price of a good one. It is very gratifying to be able to state that with the large number of specifications enforced on the Pennsylvania Railroad, where each shipment is now examined and has been for quite a period of time, the number of rejected shipments which fail to meet the specifications varies from 1.50 to 2.50 per cent., possibly sometimes a little higher. Usually the rejections are characteristic of the new specifications, that is to

say, when a specification has been out long enough so that manufacturers have had a chance to adapt themselves to its requirements, it is very rare that we have rejections.

Another point may be worth a few words, namely: Is it possible to so draw a specification that material which has once been rejected will not be offered a second time? There is, perhaps, no point connected with the specifications which is more difficult to handle than this one. It is recognized that the putting of marks on rejected shipments, as is the custom in Government work, deteriorates the quality of the rejected material, and of course adds a good deal to the cost, since the manufacturer must requite himself for the material so condemned. When materials bear serial numbers placed upon them for his own purpose by the manufacturer, the problem is less difficult, but for the mass of products which are made the subjects of specifications, such identifying marks are not available. It is perhaps fair to say that we have had shipments of rejected material returned to us, and have a second time rejected them on the second sample. Our feeling is that where there is a clause in the specification that the manufacturer must pay return freight, very few reputable people at least will run the risk of a second rejection, by returning material already once condemned. Moreover, it is not difficult to so mark rejected material with a private obscure identification mark, that it can be recognized if it is returned, and, as has been stated by one purchasing agent, it is easy to meet such cases, where the matter is free from doubt, by withholding orders from those who indulge in such practices. Our experience has been that the commercial world desires rather to do a straightforward, open, honest business, in a straightforward, honest way, and that where the specifications are reasonable, and the testing fair, there will be very little difficulty on this score.

Two points more and I have finished. First, how do specifications affect the business of producers? and, second, what is the effect of specifications on the prices of materials? Upon the first of these points let us say, we are well aware that many producers object to specifications on the ground that they are annoying and harassing, and really serve no good purpose. On the other hand we are able to say, that some manufacturers have asked that

specifications be prepared, and one large producer, indeed, told us in conversation that the more difficult the specification, the better they liked it, on the ground that it limited the competition which they would have in producing the product. There is a point here which is perhaps worth a few words. Let us suppose that an honest manufacturer is making a good product. He understands his business, and has good facilities, and is turning out an excellent article. When he comes to sales, he is called upon to meet in competition, let us assume, those who are not equally well equipped, and who in order to secure a market must offer lower prices. In order to recoup for this diminution in prices, the latter of course must make an inferior product. So long, therefore, as the consumer buys on price alone and without any specification or examination of shipments, the honest, competent manufacturer is at a disadvantage. On the other hand, if there is a good, workable specification in force and each shipment is examined, the unfair competition of the inferior manufacturer is entirely eliminated. We have many times stated in conversation with manufacturers, that in our judgment those who are doing a legitimate, straightforward, honest business, should be the strongest friends that specifications have, and it is gratifying to be able to state that many manufacturers of commercial products look at the matter in this light.

Finally, in regard to the effect of specifications on prices. Many consumers fear that if they enforce specifications, the price of the product will seriously increase. This seems a legitimate fear, and it is a fair question if the facts are as they seem to be, whether the value of the material according to the specifications is equal to the increased cost. It is gratifying to be able to state that experience indicates that after a specification has passed what may be called the "experimental stage," and is working smoothly, prices show a strong tendency to drop below the figures prevailing at the time the specification was issued. This seems to be due to two or three causes: First, the manufacturers are all bidding on the same quality of product, hence genuine competition prevails. Second, the specification describing what may be called a "staple commodity," for which there is a steady demand, slack time at the works may be employed in making this product in advance

of orders, thus employing facilities to the best advantage. Third, the constituents entering into a specification material for which there is a steady demand, can without fear of loss be purchased in large lots, and at the best stage of the market, thus securing the lowest prices. Whatever the causes, the effects on not a few materials are as stated. Of course, supply and demand are important elements in prices, and there will undoubtedly be fluctuation, but it would not be difficult to give instances in which this general tendency of specifications to lower prices is clearly seen.

Other points may be discussed or touched upon more or less at length, but I fear that I have already taken too much of your time. In order that what has preceded may be put into fairly concrete form, I beg to submit the following conclusions, as in a sense summing up what has already been said, and as putting on record our ideas on various points in the making of specifications for various materials:

1. A specification for material should contain the fewest possible restrictions, consistent with obtaining the material desired.

2. The service which the material is to perform, in connection with reasonably feasible possibilities in its manufacture, should determine the limitations of a specification.

3. All parties whose interests are affected by a specification should have a voice in its preparation.

4. The one who finally puts the wording of the specification into shape should avoid making it a place to show how much he knows, as well as a mental attitude of favor or antagonism to any of the parties affected by it.

5. Excessively severe limitations in a specification are suicidal. They lead to constant demands for concessions, which must be made if work is to be kept going, or to more or less successful efforts at evasion. Better a few moderate requirements rigidly enforced, than a mass of excessive limitations which are difficult of enforcement, and which lead to constant friction and sometimes to deception.

6. There is no real reason why a specification should not contain limitations derived from any source of knowledge. If the limitations shown by physical test are sufficient to define the

necessary qualities of the material, and this test is simplest and easiest made, the specification may reasonably be confined to this. If a chemical analysis or a microscopic examination, or a statement of the method of manufacture, or information from all four, or even other sources, are found useful or valuable in defining limitations, or in deciding upon the quality of material furnished, there is no legitimate reason why such information should not appear in the specifications. Neither the producer nor the consumer has a right to arrogate to himself the exclusive right to use information from any source.

7. Proprietary articles and commercial products, made by processes under the control of the manufacturer, cannot, from the nature of the case, be made the subject of specifications. The very idea of a specification involves the existence of a mass of common knowledge in regard to any material, which knowledge is more or less available to both producer and consumer. If the manufacturer or producer have opportunities which are not available to the consumer, of knowing how the variation of certain constituents in his product will affect that product during manufacture, so also does the consumer, if he is philosophic and is a student, have opportunities not available to the producer, of knowing how the same variation of constituents in the product will affect that product in service, and it is only by the two working together, and combining the special knowledge which each has, that a really valuable specification can be made.

8. A complete workable specification should contain the information needed by all those who must necessarily use it in obtaining the material desired. On railroads this may involve the purchasing agent, the manufacturer, the inspector, the engineer of tests, the chemist, and those who use the material. A general specification may be limited to describing the properties of the material, the method of sampling, the amount covered by one sample, and such description of the tests as will prevent doubt or ambiguity.

9. Where methods of testing or analysis or inspection are well known and understood, it is sufficient if the specification simply refers to them. Where new or unusual tests are required, or where different well-known methods give different results, it is

essential to embody in the specification sufficient description to prevent doubt or ambiguity.

10. The sample for test representing a shipment of material should always be taken at random by a representative of the consumer.

11. The amount of material represented by one sample can best be decided by the nature of the material, its importance, and its probable uniformity, as affected by its method of manufacture. No universal rule can be given.

12. The purchaser has a right to assume that every bit of the material making up a shipment meets the requirements of the specification, since this is what he contracted for and expects to pay for. It should make very little difference, therefore, what part of the shipment the sample comes from, or how it is taken. Average samples made up of a number of sub-samples are only excusable when the limits of the specification are so narrow that they do not cover the ordinary irregularities of good practice in manufacture.

13. Re-tests of material that has once failed should only be asked for under extraordinary conditions, and should be granted even more rarely than they are asked for, errors in the tests of course excepted.

14. Simple fairness requires that when it is desired that material once fairly rejected should nevertheless be used, some concession in price should be made. On the other hand, where a consumer buys material on specifications, it is equally unfair that he should ask from the producer any guarantees covering the behavior of the material in service. Furthermore, it almost goes without saying that where materials are for use in places involving the safety of life and property, rejected material should never be used.

15. Where commercial transactions are between honorable people, there is no real necessity of marking rejected material to prevent its being offered a second time. If it has failed once, it will probably fail a second time, and if return freight is rigidly collected on return shipments, the risk of loss is greater than most shippers will care to incur. Moreover, it is so easy for the consumer to put an inconspicuous private mark on rejected material, that

it is believed few will care to incur the probable loss of business that will result from the detection of an effort to dispose of a rejected shipment by offering it a second time. In this connection it may be said that those sub-employees of producers who pride themselves on working off rejected material on consumers, may in reality be doing their employers a very serious injury.

16. All specifications in actual practical daily use need revision from time to time, as new information is obtained, due to progress in knowledge, changes in methods of manufacture, and changes in the use of materials. A new specification, that is one for a material which has hitherto been bought on the reputation of the makers and without any examination as to quality, will be fortunate if it does not require revision in from six to ten months after it is first issued.

17. In the enforcement of specifications it is undoubtedly a breach of contract, legitimately leading to a rejection, if the specified tests give results not wholly within the limits, and this is especially true if the limits are reasonably wide. But it must be remembered that no tests give the absolute truth, and where the results are near, but just outside of the limit, the material may actually be all right. It seems to us better, therefore, to allow a small margin from the actual published limit, equal to the probable limit of error in the method of testing employed, and allow for this margin in the original limits, when the specifications are drawn.

18. Many producers object to specifications on the ground that they are annoying and harassing, and really serve no good purpose. It is to be feared that the complaint is just in the cases of many unwisely drawn specifications. But it should be remembered that a good, reasonable specification, carefully worked out as the result of the combined effort of both producer and consumer, and which is rigidly enforced, is the best possible protection which the honest manufacturer can have against unfair competition.

19. Many consumers fear the effect of specifications on prices. Experience seems to indicate that after a specification has passed what may be called the experimental stage, and is working smoothly, prices show a strong tendency to drop below figures prevailing before the specification was issued.

20. A complete workable specification for material represents a very high order of work. It should combine within itself the harmonized antagonistic interests of both the producer and the consumer, it should have the fewest possible requirements consistent with securing satisfactory material, should be so comprehensive as to leave no chance for ambiguity or doubt, and above all should embody within itself the results of the latest and best studies of the properties of the material which it covers.

REPORT OF COMMITTEE "A" ON STANDARD SPECIFICATIONS FOR IRON AND STEEL.

By the new scheme of enumeration recently adopted by the Executive Committee, this committee, formerly known as the enlarged American Branch of International Committee No. 1, will be hereafter designated Committee "A" on Standard Specifications for Iron and Steel.

In pursuance of a motion offered by the American representatives at the Buda-Pesth Congress of the International Association relative to the appointment of a Committee on Standard Specifications and Methods of Testing for Cast Iron and Finished Castings, the International Council appointed Messrs. Paul Kreuzpointner, Richard Moldenke and Walter Wood as additional members on the American Branch of Committee No. 1, to report on the subject of Standard Specifications, and created a new international committee, with Dr. Richard Moldenke as Vice-Chairman, to report on Uniform Methods of Testing. The above-mentioned members obtained authority from the Executive Committee for the creation of a representative American Committee on Standard Specifications for Cast Iron and Finished Castings, designated Committee "B," and at a meeting of Committee "A" held on March 10, 1903, invited all members of that committee interested in cast iron to membership.

At the last annual meeting of the Society a number of matters bearing on questions affecting the Standard Specifications for Iron and Steel were referred to Committee "A," as reported in detail in the "Summary of Proceedings," Vol. II. At a meeting of the committee held in Philadelphia on March 10, 1903, it was decided to defer formal action on these questions, pending the reports of a number of committees appointed by other societies on like or closely related subjects. One of these topics, "The Rolling of Piped Rails," has been scheduled for discussion at this meeting; others, viz.: drop tests, length and heat treatment of rails and the adoption of a single grade of

structural steel, will be brought up for discussion in connection with the various specifications to be submitted at this meeting.

Mr. J. P. Snow, Chairman of the Committee on Iron and Steel Structures of the American Railway Engineering and Maintenance of Way Association, has presented a full report on the subject of a single grade of structural steel in Bulletin No. 29 of that Association. This report, with the preliminary specifications, were submitted to our committee and discussed at a meeting held last March. The members of this committee met with Mr. Snow's committee, by invitation, at the annual convention of the American Railway Engineering and Maintenance of Way Association in Chicago last March, at which one grade of structural steel of 55,000 to 65,000 pounds ultimate strength was adopted by that Association. Mr. Snow has consented to present these specifications with some introductory remarks at this meeting.

Representatives of the leading shipbuilders, the shipping registry bureaus and the U. S. Navy, were invited to attend our meeting on March 10, to express their views with regard to the use of a single grade of steel for bridges and ships. The meeting was well attended, and the discussion was of such interest and importance that it was decided to introduce the subject for formal discussion at this session.

The Association of Steel Manufacturers, on February 6, 1903, adopted specifications for two grades of steel: the one of 55,000 to 65,000 ultimate strength for bridges, the other of 60,000 to 70,000 ultimate strength for general purposes. Mr. A. L. Colby, Secretary of the Association, will present these specifications at this session and compare them with our specifications and others. Our standard specifications were framed as fairly representative of approved American practice. It was thought that soft steel of 52,000 to 62,000 ultimate strength and medium steel of 60,000 to 70,000 ultimate strength would meet the requirements adequately for bridges and ships. If it should now be considered desirable to modify our specifications to a single grade of structural steel for bridges, what course should be pursued with regard to steel for ships? Will a steel of 55,000 to 65,000 ultimate strength, or any other single grade of steel, answer for both purposes, or should separate specifications be adopted for

ship material? In the latter case, will the medium steel of 60,000 to 70,000 ultimate strength adopted by the Association of Steel Manufacturers meet the requirements of the shipbuilders, the shipping register bureaus, and the United States Government?

The Committee on Specifications for Locomotive Axles and Forgings of the American Railway Master Mechanics' Association used our specifications as a basis for their work, and have just made a final report, at the annual convention in Saratoga, which will be presented here to-day by their Chairman, Mr. F. H. Clark, who will refer to the departures from our standard specifications.

The Committee of the American Society of Mechanical Engineers on Specifications for Steel Forgings, Steel Castings, and Steel Boiler Plate, has about completed its work, and it is to be hoped that we shall have a copy of this report before this convention closes.

The special committee of the American Society of Civil Engineers on Rail Sections has made no official report as yet, but the following extract from an editorial in the *Railroad Gazette* of January 30, 1903, indicates the conservative course this committee is taking:

"This is a short statement of the situation. The American Society's committee, so far as they are informed, would not now recommend any change of section. What it may be led to do by further information of course we shall not try to conjecture. The committee would not with its present information try to lay down specifications of chemical composition or mill treatment. The attitude of the committee, so far as we can judge, is to let the makers agree as to what is necessary in order that they may give the results sought, namely, a better and more constant quality of finished steel. If the railmakers agree that it will be for the interest of the art to make some modification in the American Society's standard sections, we suppose the committee will recommend such modification. The representatives of the railmakers, so far as we are informed, do not think any change of section is necessary, but on this they are not agreed, and this appears to be only a tentative opinion.

"As the matter now stands, the American Society's committee will probably state with some definiteness its questions and requirements, and the railmakers' committee will take these up and answer them as from the whole body of manufacturers. This, we believe, is a fair statement of the present situation, and this situation seems very promising. The attitude of the engineers is conservative

and reasonable, and the attitude of the railmakers is reasonable and liberal, and it is pretty certain that good and lasting results will be worked out by the two committees. Obviously, a matter so intricate, involving so many technical points, to say nothing of business interests, cannot be settled at once out of hand."

The Committee of the American Railway Engineering and Maintenance of Way Association on Rails suggested some modifications in their specifications at the annual convention held in Chicago last March, which I shall refer to later as Chairman of that committee.

Dr. P. H. Dudley, Reporter for America, on "Rails for Lines with Fast Trains," International Commission of the Railway Congress, has sent out a list of questions concerning rails, their manufacture, inspection, etc., as a basis for a report to the International Railway Congress, at its seventh session, to be held in Washington, D. C., in May, 1905. This subject is so closely related to the work of our committee that Dr. Dudley has been invited to suggest, at this session, in what way we can best co-operate in the matter.

It is to be hoped that the Standard Specifications of the American Associations for Testing Materials will be in suitable shape for acceptance in 1905 by the International Railway Congress as the standards for America.

While the work of our Committee has not been carried out precisely on the lines laid down by the International Association, it has been productive of very good results in this country. The same plan is now being followed in England, as appears from the following report in the *Ironmonger* of May 9, 1903, in connection with an account of the annual meeting of the Iron and Steel Institute:

"Since the formation of the committee (on standardizing the various kinds of iron and steel sections) the original reference has been enlarged to include standardization of 'Tests and Specifications,' 'Locomotives,' and 'Electrical Plant.' and important committees and sub-committees dealing with these subjects have been formed, and are now actively engaged in discussing the various subjects referred to them. There are in all fifteen different committees and sub-committees at work, composed of 102 members."

Mr. A. Rieppel, chairman of International Committee No. 1, will visit this country in the fall, at which time we shall endeavor

to have him meet Committee "A," with a view of getting our work into final shape for presentation at the St. Petersburg Congress, in August, 1905.

Respectfully submitted,

William R. Webster,
Chairman.

Edgar Marburg,
Secretary.

REPORT OF COMMITTEE "B" ON STANDARD SPECIFICATIONS FOR CAST IRON AND FINISHED CASTINGS.

This Committee is virtually a new creation since the last annual meeting of the Society. It is the outgrowth of the Congress at Buda-Pesth two years ago, where an effort was made to widen the investigation from steel and cements and to give cast iron a duly prominent position.

Following the action of the Buda-Pesth Congress, in September, 1901, the Council appointed Messrs. H. M. Howe, Walter Wood, and Richard Moldenke as additional American members of Committee No. 1 to report on standard specifications for cast iron and finished castings. These gentlemen, feeling that the object of their appointment would be better fulfilled by increasing their number, received authority from the Executive Committee for the creation of an enlarged American Committee, numbering now about seventy members.

At a meeting held April 25, 1903, the organization was perfected and the work divided among eight sub-committees. It is hoped that these sub-committees will be able to complete their work at an early date, so that it may be placed in the hands of the Executive Committee in time for presentation at the St. Petersburg Congress. This is especially desirable since the appointment of this committee was made at the instigation of the Americans at the Buda-Pesth Congress, whose request was granted with some reluctance.

Sub-committees have been appointed on the following subjects:

1. On Specifications and Grading of Pig Iron, Edgar S. Cook, Chairman.

2. On Cast-iron Water and Gas Pipe, Walter Wood, Chairman.

3. Cylinder Castings, H. V. Wille, Chairman.

4. On Car Wheels, Charles B. Dudley, Chairman.

5. On Malleable Iron, Stanley G. Flagg, Jr., Chairman.

6. On General Castings, Thomas D. West, Chairman.

7. On the Testing of Cast Iron, Henry Souther, Chairman.

8. On the Effect of Other Metals upon Cast Iron, Albert Ladd Colby, Chairman.

9. On the Microstructure of Cast Iron, Albert Sauveur, Chairman.

Appointments on these committees were made with a view of having them as representative as possible.

Sub-committee No. 1. It is hoped that this committee will present a report which will commend itself both to furnace managers and consumers, thus facilitating the buying and selling of iron by analysis, and leading to the adoption of such standards as will facilitate the purchase of iron by small users until they become ready to purchase on the basis of chemical constituents. This committee is expected to have its report in shape for the October meeting of the general Committee.

Sub-committee No. 2 will report on Cast-iron Pipe Specifications. It is fortunate that this subject received very full and careful consideration by leading engineers interested in cast-iron pipe and manufacturers during the summer of 1902. The joint results of this discussion have been put in print and will be submitted to the Committee for its consideration. It is hoped that these specifications will also be in shape for the October meeting. It may be of interest to state that the test-bar provided for is a flat bar two inches by one inch, to be broken on supports twenty-four inches apart. For pipes twelve inches or less in diameter this bar must bear a load of 1000 pounds and show a deflection of not less than 0.3 inch. For pipes larger than 12 inches it must bear a load of 2000 pounds and show a deflection of not less than 0.32 inch.

The hydraulic tests vary according to the weight of the pipes, as follows:

For Class A	150 lbs.
" " B	200 lbs.
" " C	250 lbs.
" " D	300 lbs.

The variations of thickness have been considered and, roughly speaking, a variation of 0.1 inch from the standard is permissible. However, this varies with the size of the pipe.

There is one further interesting feature embraced in these specifications, namely, what the different classes of pipe are based on standard outside diameters, the inside diameter varying with the weight and class of the pipe. The pipes are to be coated with a residuum of coal tar from which the lighter oils have been distilled at a temperature of 300°. It may be interesting to state that the Metropolitan Water Board, of Massachusetts, which supplies Boston and surrounding cities have made an elaborate investigation for finding some material which will be as satisfactory and economical as this coating. These investigations have resulted in adhering to the present method of coating, which forty years of experience has shown to be quite effective, although it does not absolutely meet the requirements of some localities.

Sub-committee No. 3, on Cylinder Castings, has held a conference, but is not yet ready to report.

Sub-committee No. 4, on Car Wheels, is fortunately represented by our President, and will at the proper time prepare specifications to be submitted for action.

Sub-committee No. 5, on Malleable Iron, has not yet prepared its final report. They hope, however, to be able to handle the subject readily and definitely.

Sub-committee No. 6 is charged with the subject of General Castings. I have a letter from Mr. Thomas D. West, Chairman, giving at some length the action taken by that committee. It is hoped that they may be able to reach some conclusion that can be applied to the various products that come under the head of General Castings. Their report will probably be based on a standard test-bar and appropriate analysis.

Sub-committee No. 7 will consider the testing of Cast Iron. The chairman of the committee, Mr. Henry Souther, expected to be at this meeting, but, failing in this, he has forwarded some correspondence. It is hoped that this committee may succeed in formulating definite methods of analysis and testing.

Sub-committee No. 8 will report on the Effect of Other Metals upon Cast Iron. From this committee no report has as yet been received.

Respectfully submitted,

WALTER WOOD,

Chairman.

DISCUSSION.

Mr. Scott.

W. G. Scott.—I wish to make a few remarks in regard to test-bars. For the last five years we have tried many kinds of test-bars at our laboratory. We have used the 1 x 1 inch bar 12 inches between supports; the 2 x 1 inch bar 2 feet between supports; and the round test-bar. For five years we have made tests with three different kinds of test-bars; they all give different results. The size of the test-bar ought to conform to the size of the work produced. The square-cornered test-bar will certainly show more imperfections, such as blow-holes, crystallized places, slag, and cavities, than the round test-bar, especially if the square or square-cornered test-bars are poured flatwise or set in an inclined position. If they are poured from the bottom or poured from the top there will be a difference. If they are poured flatwise there will be more imperfections than by pouring in any other way. The round bar would be almost a perfect bar. If I were selling cast iron I would certainly adopt the round bar; but when I am producing cast iron in my own foundry I would adopt the square-cornered bar, for the reason that I want to know when these imperfections come up, why they come up, and how to remedy them. By increasing the manganese the greater part of these imperfections may be eliminated. If the test-bar shows too much shrinkage it indicates that the sulphur is too high or the silicon too low, or that the carbon is not right. A great many other things may be judged from the test-bar. I think that, instead of adopting some standard test-bar, its choice should be left open.

Mr. Kinkead

J. C. Kinkead.—I should like to know what experience Mr. Scott has had with the one-inch square test-bar, 12 inches between centres.

Mr. Scott.

Mr. Scott.—In four or five years the deflection on the 1 x 1 inch bars has run all the way from 0.08 to 0.14 inch. The average during that time has been 0.10 inch. As to shrinkage, in casting a bar 13½ inches in yoke, as is done in some foundries, the shrinkage will depend on the portion of the heat taken from the cupola.

The first metal has a greater shrinkage than that toward the end; and there is a decrease in shrinkage all the way along the line. If you pour five bars, you will find more shrinkage in the first than you do in the last one.

Mr. Vannier. C. H. VANNIER.—I wish to say that in connection with car-wheels and the adapting of the size of the bar to the character of the casting, our standard bar in car-wheel work has been inch and a quarter square and 2 feet long, with a 600-pound wheel; but since we have been making 650-pound and 700-pound wheels we have had to change the section of our test-bars. The old section of inch and a quarter was too small, for the reason that we required harder iron for the heavier wheel. The consequence was that the iron chilled or mottled in what was our former standard bar, and consequently it did not give us the information that we wanted. The fundamental idea is that the metal in the bar shall represent as nearly as possible the metal in the body of the casting, par.icularly as to the carbons. For that reason we now make the standard size of the bar inch and a half square in pouring 700-pound wheels. In that way we keep the same relation between the carbon in the bar on the one hand and the 700-pound wheel on the other as we did between the smaller bar and the 600-pound wheel. My experience therefore fully agrees with Mr. Scott's, namely, that you must adapt the size of the test-bar to the character of the work.

Mr. Kinkead. MR. KINKEAD.—As regards adapting the size of the test-bar to the character of the work it is very easy to do this in the case of car-wheels; but when you are pouring from 2-pound to 2000-pound castings on the same afternoon from the same cupola it is very hard to do so.

Mr. Vannier. MR. VANNIER.—Where we pour two kinds of castings of different weights we also in the same heat put up two different sizes of bars; and if we are pouring 700-pound wheels, we will put up bars to correspond with the character of the work. Of course, when it comes to ordinary castings—gray-iron castings—they will be gray anyhow. Whether the casting is a quarter-inch in section or a half-inch makes no difference, except possibly in stove-plate work. There, perhaps, a half-inch bar may be used; but I do not know of any other character of work where a half-inch bar would be of service.

REPORT OF COMMITTEE "C" ON STANDARD SPECIFICATIONS FOR CEMENT.

The Committee met October 30, 1902, and organized with the following officers: Chairman, Professor George F. Swain; Vice-Chairman, George S. Webster; Secretary, Richard L. Humphrey. The membership of the committee was the subject of careful consideration, with the object of forming a large committee which should represent all the various interests involved. Subsequent to this meeting the committee was enlarged, and now consists of thirty members.

A second meeting was held February 4, 1903, and the work of the committee was discussed and a set of by-laws adopted.

It was evident that the work of the committee would consist of the adoption of standard methods for making tests, and the framing of a standard specification based on such methods. With regard to the first portion of the work, the progress report of the Committee on Uniform Tests of Cement of the American Society of Civil Engineers was adopted conditionally.

It was decided to send out samples of cement to the various members of the committee, and to such laboratories as would be willing to co-operate, and to request them to test the samples according to the rules contained in the progress report, the object being to ascertain if possible how closely the results of these tests agree, and to determine whether it is feasible to prescribe a standard specification based on these methods.

Samples of five Portland and four natural cements, with sufficient Ottawa sand, were sent to thirty laboratories, with a set of instructions and a copy of the progress report of the American Society Committee. Each laboratory was to test the samples, according to these rules, for specific gravity, fineness, time of setting, constancy of volume and tensile strength, neat and with Ottawa sand.

The results of these tests are now being sent to the Secretary, and will be compiled shortly for consideration and discussion.

They are not in such shape as to be available in whole or in part, for consideration at this time.

Your committee is obliged, therefore, to confine its report to one of progress, reserving a more complete statement of the work accomplished for a later report.

Respectfully submitted for the Committee,

GEORGE F. SWAIN,
Chairman.

REPORT OF COMMITTEE "E" ON PRESERVATIVE COATINGS FOR IRON AND STEEL.

Since the Fifth Annual Meeting of the Society, your Committee has held two general meetings and one special meeting. The membership of the committee has been increased from the original 6 to 16 members, and the committee has aimed to include representatives of every class engaged in the commercial production of Preservative Coatings.

The meetings have been confined so far to discussing the best methods of obtaining the desired data for a comprehensive report on this subject, and now, after a year's work, the committee can only submit a tentative report and outline a general scheme of action.

Before beginning this work it was considered necessary to put in concrete form several working headings:

First. Requirements for a satisfactory preservative metal coating.

Second. Methods used and suggested to determine if the preservative coating is efficient.

Third. An index, with abstracts if possible, of general and current literature bearing on this subject which has appeared in English, French, German, and American publications.

Fourth. A classified list of all coatings used or suggested for the protection of iron and steel.

The committees on the first two subjects have submitted reports; committees on the last two subjects report progress and request further time for final report.

The report of the committee on requirements for a satisfactory preservative metal coating called out a general discussion and resulted in the following recommendations:

In Preparation of Surface for Painting.—It is considered necessary that surface be free from grease and dirt, and that all detachable mill scale and rust be removed. Material which cannot be removed by hammer and chisel or wire brush, it is thought will not affect the durability of the coating. The use of the sand

blast is recommended, provided it is the opinion of the engineer that the cost is warranted, but it is not considered necessary in all cases.

Application of the Paint.—It is recommended that the successive paint coatings should be as thick as possible, compatible with satisfactory spreading with the brush or machine. The brush marks should flow out. The paint should not contain any large amounts of volatile matter, so as to chill the surface by evaporation.

Drying.—It does not seem possible, without further experimentation, to reach a final conclusion on this point. Whether the paint coats shall dry in six or twenty-four hours is a matter to be determined by the contingencies of the case. In general, it is recommended that as much time as possible be allowed between coats. It is, however, considered practicable to have an efficient metal coating dry in 8 hours.

Successive Coatings.—The under coatings must not be softened or acted upon by the subsequent coats of paint.

Protective Power.—This is the keystone of the whole subject. The coating must protect. To accomplish this it is recommended that the coating must have the maximum impermeability to moisture, air, and carbon dioxide. Iron and steel will not rust in dry air or in water free from air and carbon dioxide. The best protection will, therefore, be obtained from the most impervious coating. To this end the pigment should be as finely ground as possible. Finally, it is recommended that the vehicle or pigment, or both, be water repellent. Whether this last characteristic is to be obtained by a pigment such as lamp-black, or by the use of some non-drying oil, must be the subject for further investigation.

Durability.—It is the opinion of the committee that coatings should be efficient under ordinary conditions for at least five (5) years.

The durability measures the life of the coating; it should therefore adhere to the metal through all ranges of contraction and expansion without peeling or cracking.

Neither the pigment nor the vehicle, nor compounds resulting from a reaction of the two, should cause a disintegration of the coating.

It is further recommended that the coating should not be affected by products necessary for the maintenance, equipment, or use of the structure protected. This applies especially to the softening of paint on bridges by burning and lubricating oils from passing trains.

It is finally recommended that the coating be of such a character as to successfully resist the mechanical injury due to sand, cinders, and other material carried by the wind.

Feasibility of Recoating.—There can be no question that a satisfactory coating must permit recoating when needed without additional labor for cleaning and removing old coat.

Cost.—Upon this point it is only necessary to say that the other valuable requirements being obtained, that coating is best which can be furnished and applied at minimum cost.

Tests to Determine Efficiency of Coating.—It is the opinion of your committee that it is useless to prescribe the same tests to all classes of protective coverings. An efficient coating in the dry atmosphere of the Western States may fail to withstand the moist, saline air of the coasts.

A coating which is perfect for structural steel under a static load may fail entirely when subjected to vibratory shock imposed on bridge members and steel cars. In short, tests must be in harmony with conditions imposed in service.

The general cause of failure of coatings to protect is the same as the corrosion of the metal itself—*i. e.*, moist air and carbon dioxide.

Dilute acids, as a rule, have far less action on paint films than alkaline solutions. A paint made from some inert pigment and linseed oil will show no sign of disintegration when immersed for days in a dilute sulphuric acid solution, which would rapidly dissolve the metal it protects, and the same paint would go to pieces in a few hours when exposed to the action of a correspondingly strong solution of ammonia or carbonate or caustic alkalies.

Strong acid solutions rapidly destroy the coating, but it is rare that such conditions exist, and, if necessary, can be met by special requirements.

It is recommended that tests be adapted to the demands of service conditions, and divided into three broad classes:

First. Actual service tests, under normal conditions, applied to structure to be protected.

Second. Accelerated tests, applied to specially prepared surfaces, and subjected to abnormally severe conditions.

Third. Chemical tests to determine the constituents and adulterations of the pigment and vehicle, as far as the knowledge of the subject will admit.

It is undoubtedly true that the first set of tests gives the desired information in a most conclusive manner, but, unfortunately, the truth comes too late to remedy the evil if the protection is insufficient to prevent corrosion.

It is further considered that the function of this committee is not to specify any covering or coverings as protective, but to specify tests which coatings must stand to assure maximum efficiency.

It will therefore be necessary to work along the lines of accelerated and chemical tests, selecting those which harmonize with the results of long time service experiments, and ultimately formulating laboratory tests which can be relied upon to give desired information.

It should, however, be realized that in this work chemical analysis must be used to supplement experience, not to provide it. In general, it is known by previous experiments that certain pigments and oils give durability and protection, while others fail in these essentials; but it will not do to condemn the unknown without the aid of experience.

A review of the suggested accelerated tests shows a variety of methods to impose abnormally severe conditions. These tests have in some cases little connection to service requirements, but it is believed that the results obtained by the methods selected will be in harmony with long time service tests.

It is expected that the following series of experiments can be conducted through the co-operation of railroads and consumers on the one hand, and the manufacturers of standard coatings on the other, the former to provide the structure and labor and the latter the material to be applied.

It is recommended that two coats of the protective coating be applied to parts of full-sized structures, not less than one span

of a bridge, one steel freight car, or, in general, one unit of dimensions corresponding to above. The surface to be prepared and coating to be applied as recommended under those headings.

At the same time, panels of tank steel 20″ x 24″ x ¼″ are prepared and coated in the same manner as the structure and with the same batch of coating. The panels are coated on both sides and on edges of sheet. The work to be done indoors under favorable conditions for drying.

The panels are to have a ¼″ hole bored in middle of upper end to facilitate hanging, and are to be stamped with serial number on both sides in upper left-hand corner.

Panels are prepared as above in pairs, one to be exposed "green" and the other to be thoroughly dried under favorable conditions before testing.

The corresponding pair of "green" and dry panels are exposed under the roofs of train-sheds, in round-houses directly over smoke-stacks of engines, from trusses of bridges, on roofs of train-sheds, round-houses, and on roofs adjoining power-house stacks, etc., in tunnels, on docks in salt water and tidal rivers, where they will be immersed twice every twenty-four hours in salt and fresh water in the ebb and flow of tides.

In addition to above series of field panels, special laboratory panels on glass and tank steel are prepared in the same manner as the foregoing. The steel panels are exposed to the action of exhaust steam at a temperature not to exceed 150° F. for twelve hours each day, and ordinary atmospheric air for the remaining twelve hours, the test to be continued for thirty days.

The porosity is determined by noting the absorption of a drop of oil on the coating. If the film is impervious, the drop of oil will run down the panel in a narrow band the width of the original drop, but if the life of the coating has been destroyed the drop of oil will spread out to a more or less greasy blotch, depending on extent of disintegration.

The glass panels are tested for water-repellent properties by treating the dried coating with a few drops of water. Evaporation is prevented by means of a cover-glass, and the coating examined after the water has been in contact for 12 hours.

The capacity of the coating to withstand destructive agencies

necessary to equipment and maintenance of structure will require special tests.

For steel cars and bridges the coating on glass is tested with lubricating and burning oils to determine if it is disintegrated. For refrigerating cars it is tested in the same manner with a common salt solution.

A further set of laboratory tests are made by coating saucers of sheet iron 8" diameter 1" deep with two coats of paint. These saucers are filled with ordinary tap water and allowed to evaporate under cover to dryness; the water renewed until definite conclusions can be deduced.

Chemical analyses of the coatings will also be made to determine percentage of pigment, oil, and volatile matter, with composition and quality of each.

The above service and laboratory tests are to be conducted at as widely distant points and under as different conditions as possible. The service tests are to be carefully examined at stated intervals, and the entire series of experiments accurately tabulated for comparison with the long time service tests.

From this data it is expected that laboratory tests can be formulated, which, when met, will insure a satisfactory protective metal coating.

Respectfully submitted,

[Signed] S. S. VOORHEES, *Chairman*,
W. A. AIKEN,
CHAS. B. DUDLEY,
N. F. HARRIMAN,
INTERNATIONAL ACHESON GRAPHITE CO.,
ROBERT JOB,
JOSEPH DIXON CRUCIBLE CO.,
SPENCER B. NEWBERRY,
CHAS. L. NORTON,
PATTERSON-SARGENT CO.,
W. A. POWERS,
A. H. SABIN,
THE A. WILHELM CO.,
JOSEPH F. WALKER,
J. W. WHITEHEAD, JR.,
MAX H. WICKHORST.

DISCUSSION.

S. S. Voorhees.—I want to emphasize the fact that this report can only be considered a tentative one, outlining in general a scheme of action, which may be followed or may be found to require modification, as there are one or two points which might be changed a little. Mr. Voorhees.

It is not the intention of the Committee to exclude any special paint. We tried to emphasize the fact that any paint which meets the requirements of tests will be satisfactory as a preservative coating. There are certain paints with lead pigments which solidify in the bucket, but if they have valuable features sufficient to counterbalance this objection they will meet requirements.

The President.—How does the matter stand with regard to the unanimity of the Committee? The President.

Mr. Voorhees.—This report was intended to be accepted *in toto* by the Committee; but there are several minor points which possibly were not—for instance, the five-year clause is one; the question of the solidifying of the paint in the bucket is another; and the extent of cleaning before painting is a third. The character of the tests has also been in some cases thought excessively severe, and in other cases not severe enough; but, as I said, it is simply a tentative report which will be worked on during the next year, and these tests can then be brought down to a more definite basis. Mr. Voorhees.

It would probably be well to strike out the clause "It is also considered objectionable if paints solidify in the buckets," as a certain class of protective paints have that fault—or value, because this solidifying is really a cementing action which is an advantage if it occurs on the metal to be protected; but if the caking occurs in the bucket, that cementing action is lost. That clause will be removed from the present report before it is printed.

The President.—The principal difficulty as we understand it with red lead is that if perchance more is mixed up at any one time than is spread, it hardens in the buckets, especially if it stands The President.

The President. overnight. There are two ways of overcoming this difficulty: one is to mix frequently and in small amounts: the other is to mix some inert material with the red lead. We have had good success in using a material consisting of pure red lead two parts and kaolin one part, made into a stiff paste with linseed oil. Lamp-black has also been used to overcome this difficulty, and, so far as our knowledge goes, this is unobjectionable.

For the railroads the protection of steel cars is getting to be a very serious matter. Steel cars cost from $1000 to $1200 each. How long are they going to last? You will readily see that if corrosion goes on rapidly the loss will be serious. Apparently we are in a dilemma. Proper sizes of wood are becoming more and more difficult to get, and there seems nothing to do but to use the steel car. If the corrosion leads to short life, the losses may be very serious. We have one or two rays of light. An examination was made some time ago of the layer of rust that had formed on the inside of several steel cars of the first lot built for the Pennsylvania Railroad. These cars had no protective coating of any kind on the inside. At the end of two years and three months of service a scale was formed which was detached and sent to the laboratory, with a request to know how much of the original material this scale corresponded to. An analysis of a measured area indicated that one-fiftieth of an inch of the thickness of the original metal had already corroded to form this scale. Some three or four cars gave approximately the same figure. A calculation based on this rate of corrosion indicated that if the car was still available for service when one-half the metal had corroded, the life of a car would be about fourteen years, which is much more gratifying than we feared. The second ray of light which we have is more a hope than something definitely in sight. It is that protective coatings of some kind are now available, or will be devised, which will be sufficient to give a fairly long life to the steel car.

Mr. Sabin. A. H. SABIN.—It is only fair to say, I think, in reference to this report, that Mr. Aiken, who had in hand the matter of preparing an outline sketch of the method of testing, was unable to act owing to accident. He had a fractured leg and was in the hospital. It occurred at the time when he was collecting material for the report:

consequently that part of the report which deals with the tests is quite incomplete, and represents various views held by various members of the Committee. I wish to say also that the Insurance Engineering Experiment Station at Boston has been asked to send a man to represent them on this Committee, and we hope that this will be done. What seems to me the most immediately important work of the Committee is that which refers to the collection of papers, or at least of references to papers on the subject, looking up the literature of the matter. Several members of the Committee were asked by the chairman to undertake different parts of this work; but upon investigating the matter somewhat each found that the part assigned to himself was so great that he could not get the time to do it. There is a good deal of material to be gotten together, and it is hoped that in some way in the future something of value may be done in this direction. Until we know what has been done by others, it is certainly premature to go ahead and try to do very much ourselves. Mr. Sabin.

E. PLATT STRATTON.—On behalf of the Society, I think the thanks of its members are due to the formulators of this Report, and in this connection I recall a time, several years since, when the British Parliament appointed a Special Committee of Experts to collect information and data bearing upon the best anti-corrosives and anti-fouling pigments for use on ships' plating, particularly below the water-line. The outcome of that investigation, which extended over a considerable period, was McGuinnis' Compound, generally known among shipping men as one of the best coatings ever invented for use under water; but painters and ship-owners have been groping, so to speak, more or less in the dark for years in relation to this very important subject, and I am greatly surprised and much gratified to see this matter so competently dealt with at this time and by a Committee of this Society. Mr. Stratton.

There are, however, in the marine field, two distinct conditions to be dealt with: one is with plating and surfaces below the water-line, where you encounter the troubles and difficulties incident to marine growths and mollusk life which affix themselves with much tenacity to the painted surfaces. All such growth and life when once attached soon develop increased resistance and seriously retard the vessel's progress through the water until removed

Mr. Stratton. mechanically, unless the pigment is made to contain elements that are destructive to such growths and marine life at the start. The second relates to the internal surfaces of metallic ships, where the conditions are different but are no less important in character. All the internal portions of the hulls of vessels liable to be touched or affected by bilge-water and the contaminations of it by the drippings or seapage from cargoes are required to be thoroughly coated with a mixture of Portland or hydraulic cement and sand mixed in about equal parts and laid on with a trowel. Bitumastic cement has been substituted in some instances on account of its reduced weight compared with the former, which is less likely to be affected detrimentally by climatic changes, and is to be regarded as more enduring under all conditions.

About twenty years since naval architects and shipbuilders began the construction of vessels with double bottoms, extending from bilge to bilge all fore and aft over the entire floor of the vessel, such space being subdivided longitudinally at the centre by a vertical keelson and transversely into from ten to twenty compartments, the lower or outside plating being well cemented inside to prevent wear and corrosion and to stiffen the plating between the floors. Owing to the inaccessibility of the many parts of the framing existing between the outer and inner bottom, which seldom exceeds thirty-six to forty inches in depth, it was at first thought the material in these spaces would deteriorate very rapidly incident to the emptying and filling of these waterbottoms for ballast with all sorts of impure water, wherever and whenever it might be found necessary to fill them; but experience has shown that "the active agent in the corrosion is the carbonic acid of the atmosphere which, in the presence of moisture and oxygen, forms compounds with the iron which are unstable and after formation break up, leaving the carbonic acid free to continue its work," and the difficulty is practically overcome by keeping these spaces closed to the air except when such vessels are placed on dry-dock, when the plugs of the limbers are opened and the space between the outer and inner bottoms thoroughly washed out with hose.

The Committee's report certainly gives us all much enlightenment on this subject, which few of us have any time or inclination to exploit.

REPORT OF COMMITTEE "G" ON THE MAGNETIC PROPERTIES OF IRON AND STEEL.

The Committee recently appointed to investigate the subject of "The Magnetic Properties of Iron and Steel," as a result of a meeting held at New York City June 26, 1903, submits the following for your consideration:

1. That for the present, at least, the Committee will consider, in its investigations, only those subjects which have a bearing of practical, commercial importance.

2. That with the approval of the Society, the Committee will attempt the preparation of a bibliography of the literature in the English, French, and German languages relating to the subject at hand.

3. To the end that an attempt at standardization of magnetic materials and means and methods of testing may be successful, the Committee proposes to conduct the necessary investigations and research to enable it to recommend a method of obtaining samples for magnetic tests, and a rapid, yet sufficiently accurate means of making magnetic determinations on the different kinds of iron and steel in commercial use.

4. A chemical, magnetic, and microscopic study of cast steel, with a view to ascertaining those mixtures and heat treatments which produce the best magnetic iron consistent with other requirements.

5. A similar study of cast iron, except in so far as the above refers to heat treatment.

6. A chemical, magnetic, and microscopic study of steel for permanent magnets.

7. Investigation of methods of hardening steel for permanent magnets, with the hope of being able to recommend the methods which, for the different alloys, will result in the highest quality consistent with the other requirements of the process and product.

8. A study of the deterioration of permanent magnets of different alloy, under varied conditions.

9. A chemical, magnetic, and microscopic study of sheet steel under varied heat treatments.

It is entirely possible that in course of the investigations herein outlined new lines of research may be suggested, and further that not all of the work set forth will be begun during the ensuing year. To the Committee, it appears highly desirable that all the light possible be brought to bear upon the literature of the subject, and that the methods of conducting the tests be as thoroughly systematized as possible prior to the beginning of some of the lines of research.

Respectfully submitted,

J. WALTER ESTERLINE, *Chairman*,
JOHN A. CAPP,
H. E. DILLER,
W. A. LAYMAN,
J. A. MATHEWS,
RICHARD MOLDENKE,
R. B. TREAT.

SPECIFICATIONS FOR IRON AND STEEL STRUCTURES ADOPTED BY THE AMERICAN RAILWAY ENGINEERING AND MAINTENANCE OF WAY ASSOCIATION IN MARCH, 1903.

WITH INTRODUCTION BY J. P. SNOW, CHAIRMAN.

The development of the specifications for material that were adopted at the annual meeting of the American Railway Engineering and Maintenance of Way Association in March, 1903, may be said to have commenced with the report of the Committee on Iron and Steel Structures at the annual meeting of March, 1901.

At that meeting the specifications presented in 1900 by the American Branch of Committee No. 1 of the International Association for Testing Materials, at the New York meeting of the American Section (now the American Society for Testing Materials), were put forth as a basis, and certain modifications recommended. These recommendations called for two grades of structural steel with limits of 52,000 to 60,000, and 60,000 to 68,000, with rivet steel 50,000 to 58,000. The usual requirements for yield point and elastic limit were prescribed, but rather severe bending tests were called for, inasmuch as the bending specimens were to be left with sheared edges.

Two valuable schedules were presented showing the great lack of uniformity in the practice of American engineers and railroads. The discussion turned mainly on minor points, without touching upon the central feature of grade of steel to be recommended.

The following year the members of the Committee were unable to agree on the question of grade of steel, and presented a progress report only. Five of the nine members voted for two grades, viz.: tensile strength, 51,000 to 59,000 and 61,000 to 69,000, and four voted for a single grade of 55,000 to 65,000 tensile strength. Both of these schemes departed radically from the time-honored practice of two grades which covered everything from 52,000 to 68,000, the grades either meeting at 60,000 or lapping so that 60,000 to 62,000 was common to both grades. The subject was

vigorously discussed in the Committee and by the Association at the annual meeting. The advocates of the single grade claimed that the average proposed, viz.: 60,000 pounds tensile strength, is the natural product of the basic open-hearth furnace, which is the present-day method of making structural steel; that it could be safely used without reaming up to 5–8″ thick, but would be improved by reaming if such improvement were desired, and that if the two-grade scheme were adopted, it would be very difficult to get the metal that they considered the most desirable, viz.: 60,000 pounds tensile strength, because manufacturers would shun it, as it would be barred out of either grade.

The advocates of the two-grade scheme proposed the zone of difference for the reason that it was difficult under the old-time scheme to obtain material ranging as high as they desired in reamed work, thinking that if two distinct grades with a gap between were established it would induce manufacturers to produce material more suitable for their purpose. Moreover, believing 68,000 to 70,000-pound material to be perfectly safe when reamed and planed, they were reluctant to limit the upper grade to 65,000 pounds.

The Committee for the following year (1902–1903), consisting of ten members, canvassed the matter thoroughly during the year. The result was an agreement of all the members on a single grade averaging 60,000 pounds for structural steel and a material not over 55,000 pounds for rivets. This as embodied in the specifications before you was adopted by the Association after considerable discussion.

At the Atlantic City meeting of this Society in June, 1902, the question of the desirability of recommending a single grade of steel for structural work was discussed. The matter was referred back to Committee No. 1, with the general understanding that the action of other societies was to be studied, especially that of the Maintenance of Way Association. It seems appropriate therefore to present the conclusions of that body here, with the above statement of the course of events leading up to the result.

Mr. William R. Webster has taken a very active part in furthering the work of the Committee and in bringing the matter to a satisfactory conclusion. He has interested prominent engi-

neers and shipbuilders in the question of a single grade of structural material, with the result of bringing out much support for the scheme. Since the single grade idea was brought prominently forward, many large railroads have adopted it in their specifications. The Cramp Ship and Engine Building Company write that they consider the grade proposed satisfactory for the frame and sheathing of ships. We are assured by nearly all the large steel manufacturers that the grade is satisfactory to them, and it is very close to the generally adopted standards of European countries.

On the matter of mill testing the feeling of the Committee is that more importance should be put upon full-sized cold bending than has been customary in the past. The tensile tests and chemical investigations show the grade of steel and the work of the furnace, but to check the work of the rolls, the reheating furnaces, if any are used, and the final heat treatment, it is thought that cold bending, either plain or nicked, is indispensable.

SPECIFICATIONS FOR MATERIAL AND WORKMANSHIP FOR STEEL STRUCTURES.

MATERIAL.

1. Steel shall be made by the open-hearth process.

2.

Chemical and Physical Properties.	Structural Steel.	Rivet Steel.	Steel Castings.
Phosphorus max. Basic	0.04 per cent.	0.04 per cent.	0.05 per cent.
Phosphorus max. Acid	0.08 " "	0.04 " "	0.08 " "
Sulphur maximum	0.05 " "	0.04 " "	0.05 " "
Ultimate tensile strength. Pounds per square inch	Desired. 60,000	Desired. 50,000	Not less than 65,000
Elongation: min. % in 8"	1,500,000* / Ult. tensile strength.	1,500,000 / Ult. tensile strength.	
" " % in 2"	22	....	18
Character of fracture	Silky.	Silky.	Silky or fine granular.
Cold bends without fracture	180° flat.†	180° flat.‡	90°

* See paragraph 11. † See paragraphs 12, 13, and 14. ‡ See paragraph 15.

The yield point, as indicated by the drop of beam, shall be recorded in the test reports.

3. Tensile tests of steel showing an ultimate strength within 5,000 lbs. of that desired will be considered satisfactory, except that if the ultimate strength

varies more than 4,000 lbs. from that desired, a retest shall be made on the same gage, which, to be acceptable, shall be within 5,000 lbs. of the desired ultimate.

4. Chemical determinations of the percentages of carbon, phosphorus, sulphur and manganese shall be made by the manufacturer from a test ingot taken at the time of the pouring of each melt of steel and a correct copy of such analysis shall be furnished to the engineer or his inspector. Check analyses shall be made from finished material, if called for by the purchaser, in which case an excess of 25 per cent. above the required limits will be allowed.

5. PLATES, SHAPES AND BARS: Specimens for tensile and bending tests for plates, shapes and bars shall be made by cutting coupons from the finished product, which shall have both faces rolled and both edges milled to the form shown by Fig. 1; or with both edges parallel; or they may be turned to a diameter of ¾ inch for a length of at least 9 inches, with enlarged ends.

6. RIVETS: Rivet rods shall be tested as rolled.

7. PINS AND ROLLERS: Specimens shall be cut from the finished rolled or forged bar, in such manner that the center of the specimen shall be 1 inch from the surface of the bar. The specimen for tensile test shall be turned to the form shown by Fig. 2. The specimen for bending test shall be 1 inch by ½ inch in section.

8. STEEL CASTINGS: The number of tests will depend on the character and importance of the castings. Specimens shall be cut cold from coupons molded and cast on some portion of one or more castings from each melt or from the sink heads, if the heads are of sufficient size. The coupon or sink head, so used, shall be annealed with the casting before it is cut off. Test specimens to be of the form prescribed for pins and rollers.

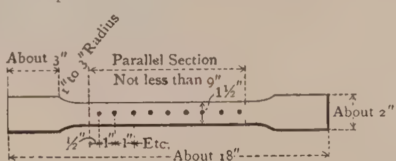


FIG. 1.

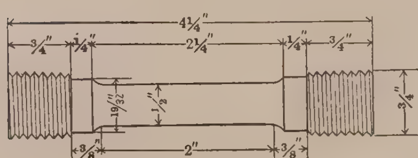


FIG. 2.

9. Material which is to be used without annealing or further treatment shall be tested in the condition in which it comes from the rolls. When material is to be annealed or otherwise treated before use, the specimen representing such material shall be similarly treated before testing.

10. At least one tensile and one bending test shall be made from each melt of steel as rolled. In case steel differing ⅜ inch and more in thickness is rolled from one melt, a test shall be made from the thickest and thinnest material rolled.

11. For material less than 5-16 inch and more than ¾ inch in thickness the following modifications will be allowed in the requirements for elongation:

(*a*) For each 1-16 inch in thickness below 5-16 inch, a deduction of 2½ per cent. will be allowed from the specified elongation.

(*b*) For each ⅛ inch in thickness above ¾ inch, a deduction of 1 per cent. will be allowed from the specified elongation.

(*c*) For pins and rollers over 3 inches in diameter the elongation in 8 inches may be 5 per cent. less than that specified in paragraph 2.

12. Bending tests may be made by pressure or by blows. Plates, shapes and bars less than 1 inch thick shall bend as called for in paragraph 2.

13. Full-sized material for eye-bars and other steel 1 inch thick and over shall bend cold 180° around a pin the diameter of which is equal to twice the thickness of the bar, without fracture on the outside of bend.

14. Angles ¾ inch and less in thickness shall open flat, and angles ½ inch and less in thickness shall bend shut, cold, under blows of a hammer, without sign of fracture. This test will be made only when required by the inspector.

15. Rivet steel, when nicked and bent around a bar of the same diameter as the rivet rod, shall give a gradual break and a fine, silky, uniform fracture.

16. Finished material shall be free from injurious seams, flaws, cracks, defective edges, or other defects, and have a smooth, uniform, workmanlike finish.

17. Every finished piece of steel shall have the melt number and the name of the manufacturer stamped or rolled upon it. Steel for pins and rollers shall be stamped on the end. Rivet and lattice steel and other small parts may be bundled with the above marks on an attached metal tag.

18. Material which, subsequent to the above tests at the mills and its acceptance there, develops weak spots, brittleness, cracks or other imperfections, or is found to have injurious defects, will be rejected at the shop and shall be replaced by the manufacturer at his own cost.

19. A variation in cross-section or weight of each piece of steel of more than 2½ per cent. from that specified will be sufficient cause for rejection, except in case of sheared plates, which will be covered by the following permissible variations, which are to apply to single plates.

WHEN ORDERED TO WEIGHT.

20. Plates 12½ pounds per square foot or heavier:

(*a*) Up to 100 inches wide, 2½ per cent. above or below the prescribed weight.

(*b*) One hundred inches wide and over, 5 per cent. above or below.

21. Plates under 12½ pounds per square foot:

(*a*) Up to 75 inches wide, 2½ per cent. above or below.

(*b*) Seventy-five inches and up to 100 inches wide, 5 per cent. above or 3 per cent. below.

(*c*) One hundred inches wide and over, 10 per cent. above or 3 per cent. below.

WHEN ORDERED TO GAGE.

22. Plates will be accepted if they measure not more than 0.01 inch below the ordered thickness.

23. An excess over the nominal weight, corresponding to the dimensions on the order, will be allowed for each plate, if not more than that shown in the following tables, one cubic inch of rolled steel being assumed to weigh 0.2833 pound.

24. Plates ¼ inch and over in thickness.

Thickness Ordered.	Nominal Weights.	Width of Plate.			
		Up to 75 inch.	75" and up to 100".	100" and up to 115".	Over 115".
1-4 inch.	10.20 lbs.	10 per cent.	14 per cent.	18 per cent.	
5-16 "	12.75 "	8 " "	12 " "	16 " "	
3-8 "	15.30 "	7 " "	10 " "	13 " "	17 per cent.
7-16 "	17.85 "	6 " "	8 " "	10 " "	13 " "
1-2 "	20.40 "	5 " "	7 " "	9 " "	12 " "
9-16 "	22.95 "	4½ " "	6½ " "	8½ " "	11 " "
5-8 "	25.50 "	4 " "	6 " "	8 " "	10 " "
Over 5-8 "	....	3½ " "	5 " "	6½ " "	9 " "

25. Plates under ¼ inch in thickness.

Thickness Ordered.	Nominal Weights. Lbs. per square ft.	Width of Plate.		
		Up to 50".	50" and up to 70".	Over 70".
1-8" up to 5-32"	5.10 to 6.37	10 per cent.	15 per cent.	20 per cent.
5-32" " 3-16"	6.37 " 7.65	8½ " "	12½ " "	17 " "
3-16" " 1-4"	7.65 " 10.20	7 " "	10 " "	15 " "

INSPECTION AND TESTING AT THE MILLS.

26. The purchaser shall be furnished complete copies of mill orders, and no material shall be rolled, nor work done, before the purchaser has been notified where the orders have been placed, so that he may arrange for the inspection.

27. The manufacturer shall furnish all facilities for inspecting and testing the weight and quality of all material at the mill where it is manufactured. He shall furnish a suitable testing machine for testing the specimens, as well as prepare the pieces for the machine, free of cost.

28. When an inspector is furnished by the purchaser to inspect material at the mills, he shall have full access, at all times, to all parts of mills where material to be inspected by him is being manufactured.

WORKMANSHIP.

29. All parts forming a structure shall be built in accordance with approved drawings. The workmanship and finish shall be equal to the best practice in modern bridge works.

30. Material shall be thoroughly straightened in the shop, by methods that will not injure it, before being laid off or worked in any way.

31. Shearing shall be neatly and accurately done and all portions of the work exposed to view neatly finished.

32. The size of rivets, called for on the plans, shall be understood to mean the actual size of the cold rivet before heating.

33. When general reaming is not required, the diameter of the punch for material not over $\frac{5}{8}$ inch thick shall be not more than 1-16 inch, nor that of the die more than $\frac{1}{8}$ inch larger than the diameter of the rivet. Material over $\frac{5}{8}$ inch thick, except minor details, and all material where general reaming is required, shall be sub punched and reamed as per paragraph 61, or drilled from the solid. Rolled beams and channels used in floors of railroad bridges shall be sub-punched and reamed, or drilled from the solid.

34. Punching shall be accurately done. Slight inaccuracy in the matching of holes may be corrected with reamers. Drifting to enlarge unfair holes will not be allowed. Poor matching of holes will be cause for rejection at the option of the inspector.

35. Riveted members shall have all parts well pinned up and firmly drawn together with bolts before riveting is commenced. Contact surfaces to be painted (see paragraph 65).

36. Lattice bars shall have neatly rounded ends, unless otherwise called for.

37. Stiffeners shall fit neatly between flanges of girders. Where tight fits are called for, the ends of the stiffeners shall be faced and shall be brought to a true contact bearing with the flange angles.

38. Web splice plates and fillers under stiffeners shall be cut to fit within $\frac{1}{8}$ inch of flange angles.

39. Web plates of girders, which have no cover plates, shall be flush with the backs of angles or project above the same not more than $\frac{1}{8}$ inch, unless otherwise called for. When web plates are spliced, not more than $\frac{1}{4}$ inch clearance between ends of plates will be allowed.

40. Connection angles for floor girders shall be flush with each other and correct as to position and length of girder. In case milling is required after riveting, the removal of more than 1-16 inch from their thickness will be cause for rejection.

41. Rivets shall be driven by pressure tools wherever possible. Pneumatic hammers shall be used in preference to hand driving.

42. Rivets shall look neat and finished, with heads of approved shape, full and of equal size. They shall be central on shank and grip the assembled pieces firmly. Recupping and calking will not be allowed. Loose, burned or otherwise defective rivets shall be cut out and replaced. In cutting out rivets great care shall be taken not to injure the adjacent metal. If necessary they shall be drilled out.

43. Wherever bolts are used in place of rivets which transmit shear, the holes shall be reamed parallel and the bolts turned to a driving fit. A washer not less than $\frac{1}{4}$ inch thick shall be used under nut.

44. The several pieces forming one built member shall be straight and fit closely together, and finished members shall be free from twists, bends or open joints.

45. Abutting joints shall be cut or dressed true and straight and fitted close together, especially where open to view. In compression joints depending on contact bearing the surfaces shall be truly faced, so as to have even bearings after they are riveted up complete and when perfectly aligned.

46. Holes for floor girder connections shall be sub-punched and reamed with twist drills to a steel template 1 inch thick. Unless otherwise allowed, all other field connections shall be assembled in the shop and the unfair holes reamed; and when so reamed the pieces shall be match-marked before being taken apart.

47. Eye-bars shall be straight and true to size, and shall be free from twists, folds in the neck or head, or any other defect. Heads shall be made by upsetting, rolling or forging. Welding will not be allowed. The form of heads will be determined by the dies in use at the works where the eye-bars are made, if satisfactory to the engineer, but the manufacturer shall guarantee the bars to break in the body with a silky fracture when tested to rupture. The thickness of head and neck shall not vary more than 1-16 inch from the thickness of the bar.

48. Before boring, each eye-bar shall be properly annealed and carefully straightened. Pin holes shall be in the center line of bars and in the center of heads. Bars of the same length shall be bored so accurately that, when placed together, pins 1-32 inch smaller in diameter than the pin holes can be passed through the holes at both ends of the bars at the same time.

49. Pin holes shall be bored true to gauges, smooth and straight, at right angles to the axis of the member and parallel to each other, unless otherwise called for. Wherever possible, the boring shall be done after the member is riveted up.

50. The distance center to center of pin holes shall be correct within 1-32 inch, and the diameter of the hole not more than 1-50 inch larger than that of the pin, for pins up to 5 inches diameter, and 1-32 inch for larger pins.

51. Pins and rollers shall be accurately turned to gauges and shall be straight and smooth and entirely free from flaws.

52. At least one pilot and driving nut shall be furnished for each size of pin for each structure.

53. Screw threads shall make tight fits in the nuts and shall be United States standard, except at ends of pins and for bolts over 1½ inches in diameter, for which six threads per inch shall be used.

54. Steel, except in minor details, which has been partially heated shall be properly annealed.

55. All steel castings shall be annealed.

56. Welds in steel will not be allowed.

57. Expansion bed plates shall be planed true and smooth. Cast wall plates shall be planed top and bottom. The cut of the planing tool shall correspond with the direction of expansion.

58. Pins, nuts, bolts, rivets and other small details shall be boxed or crated.

59. The weight of every piece and box shall be marked on it in plain figures.

ADDITIONAL SPECIFICATIONS WHEN GENERAL REAMING AND PLANING ARE REQUIRED.

60. Sheared edges and ends shall be planed off at least ¼ inch.

61. Punched holes shall be made with a punch 3-16 inch smaller in diameter than the nominal size of the rivets and shall be reamed to a finished diameter of not more than 1-16 inch larger than the rivet.

62. Wherever practicable, reaming shall be done after the pieces forming one built member have been assembled and firmly bolted together. If necessary to take the pieces apart for shipping and handling, the respective pieces reamed together shall be so marked that they may be reassembled in the same position in the final setting up. No interchange of reamed parts will be allowed.

63. The burrs on all reamed holes shall be removed by a tool countersinking about 1-16 inch.

SHOP PAINTING.

64. Steel work, before leaving the shop, shall be thoroughly cleaned and given one good coating of pure linseed oil, or such paint as may be called for, well worked into all joints and open spaces.

65. In riveted work, the surfaces coming in contact shall each be painted before being riveted together.

66. Pieces and parts which are not accessible for painting after erection, including tops of stringers, eye-bar heads, ends of posts and chords, etc., shall have a good coat of paint before leaving the shop.

67. Painting shall be done only when the surface of the metal is perfectly dry. It shall not be done in wet or freezing weather, unless protected under cover.

68. Machine-finished surfaces shall be coated with white lead and tallow before shipment or before being put out into the open air.

INSPECTION AND TESTING AT THE SHOPS.

69. The manufacturer shall furnish all facilities for inspecting and testing weight and the quality of workmanship at the shop where material is manufactured. He shall furnish a suitable testing machine for testing full-sized members if required.

70. The purchaser shall be furnished complete shop plans, and must be notified well in advance of the start of the work in the shop, in order that he may have an inspector on hand to inspect material and workmanship. Complete copies of shipping invoices shall be furnished to the purchaser with each shipment.

71. When an inspector is furnished by the purchaser, he shall have full access, at all times, to all parts of the shop where material under his inspection is being manufactured.

72. The inspector shall stamp each piece accepted with a private mark. Any piece not so marked may be rejected at any time, and at any stage of the work. If the inspector, through an oversight or otherwise, has accepted material or work which is defective or contrary to the specifications, this material, no matter in what stage of completion, may be rejected by the purchaser.

FULL-SIZED TESTS.

73. Full-sized parts of the structure may be tested at the option of the purchaser. If tested to destruction, such material shall be paid for at cost, less its scrap value, if it proves satisfactory.

74. If it does not stand the specified tests, it will be considered rejected material and be solely at the cost of the contractor, unless he is not responsible for the design of the work.

75. In eye-bar tests the ultimate strength, true elastic limit and the elongation in 10 feet, unless a different length is called for, shall be recorded.

76. In transverse tests the lateral and vertical deflections shall be recorded.

J. P. SNOW, Bridge Engineer, Boston & Maine Railroad, Boston, Mass., *Chairman;*

B. DOUGLAS, Bridge Engineer, Michigan Central Railroad, Detroit, Mich., *Vice-Chairman;*

JOHN BRUNNER, Assistant General Superintendent, North Works, Illinois Steel Company, Chicago, Ill.;

T. L. CONDRON, Consulting Engineer, Chicago, Ill.;

C. L. CRANDALL, Professor of Railroad Engineering, Cornell University, Ithaca, N. Y.;

J. E. GREINER, Engineer of Bridges and Buildings, Baltimore and Ohio Railroad, Baltimore, Md.;

WM. M. HUGHES, Consulting Bridge Engineer, Chicago, Ill.;

WM. MICHEL, Engineer Maintenance-of-Way, Hocking Valley Railroad, Columbus, O.;

C. C. SCHNEIDER, Vice-President American Bridge Company, New York, N. Y.;

J. R. WORCESTER, Consulting Engineer, Boston, Mass.,

Committee.

SPECIFICATIONS FOR LOCOMOTIVE AXLES AND FORGINGS PREPARED BY A COMMITTEE OF THE AMERICAN RAILWAY MASTER MECHANICS' ASSOCIATION.

WITH INTRODUCTION BY F. H. CLARK, CHAIRMAN.

I would say by way of introduction that the American Railway Master Mechanics' Association appointed a committee last year with instructions to present specifications for locomotive forgings and for driving and engine truck axles, to consult with this Society and with others interested and to try to have ready by the time of the International Railway Congress of 1905 satisfactory specifications for the material referred to. We have accordingly prepared three specifications—one for locomotive driving and engine truck axles, one for locomotive forgings, and one for steel blooms and billets for locomotive forgings. In a general way the work of our Committee conforms quite closely to the specifications adopted by your Society two years ago.

Our Committee has considered pretty carefully in connection with the method of taking the test pieces for axles, the question of reduction in strength, and we cannot find that the strength will be appreciably affected. The depth of the hole made by the hollow drill is somewhat less than the width of wheel fit, say from two-thirds to three-fourths, so that the weakening is very slight.

PROPOSED SPECIFICATIONS FOR LOCOMOTIVE DRIVING AND ENGINE TRUCK AXLES.

MATERIAL.

Open Hearth Steel.

CHEMICAL REQUIREMENTS.

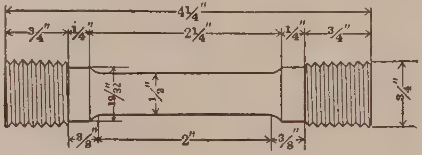
Phosphorus, not to exceed..........	0.05	per cent.
Sulphur, " "	0.05	"
Manganese, " "	0.60	"

PHYSICAL REQUIREMENTS.

Tensile strength, not less than 80,000 pounds per sq. inch.
Elongation in two inches, not less than 20 per cent.
Reduction in area, not less than 35 per cent.

NUMBER OF TESTS.

One test per melt will be required, the test specimen to be taken from either end of any axle with a hollow drill, half-way between the center and the outside, the hole made by the drill to be not more than two inches in diameter, nor more than 4½ inches deep. The standard turned test specimen, one-half inch in diameter and two inches gauge length, shall be used to determine the physical properties. (See figure.) Drillings or turnings from the tensile specimens shall be used to determine the chemical properties.



STAMPING AND MARKING.

Each axle must have heat number and manufacturer's name, plainly stamped on one end, with stamps not less than ⅜ inch, and have order number plainly marked with white lead.

INSPECTION.

All axles must be free from seams, pipes, and other defects, and must conform to drawings accompanying these specifications.

Axles must be rough-turned all over, with a flat-nosed tool, cut to exact length, have ends smoothly finished and centered with sixty-degree centers.

Axles failing to meet any of the above requirements, or which prove defective on machining, will be rejected.

The above specification for locomotive driving and truck axles is believed to be fair to both manufacturer and purchaser. The physical test outlined is one which should insure proper hammer work and it has also the following further points in its favor:

(1) It does not show the manufacturer which axle is to be selected for test.

(2) The axle tested is not destroyed, but is available for use if it meets the requirements.

(3) The test may be used in the purchase of small lots, most orders from railroad companies being for from six to ten axles.

(4) The test does not require a discard and in no way adds to the cost of the axle.

(5) It furnishes the manufacturer with a check of the work done in his plant.

(6) The test is one largely used by the United States Government for forgings.

PROPOSED SPECIFICATIONS FOR LOCOMOTIVE FORGINGS.

MATERIAL.

Open Hearth Steel.

CHEMICAL REQUIREMENTS.

Phosphorus, not to exceed..........	0.05	per cent.
Sulphur, " "	0.05	"
Manganese, " "	0.60	"

PHYSICAL REQUIREMENTS.

Tensile strength, not less than 80,000 pounds per square inch.
Elongation, not less than 20 per cent. in two inches.
Reduction in area, not less than 35 per cent.

NUMBER OF TESTS.

One test per melt will be required, the test specimen to be cut cold from the forging, or full-sized prolongation of same, parallel to the axis of the forging and half-way between the center and the outside.

The standard turned specimen, one-half inch in diameter and two inches gauge length, shall be used to determine the physical properties. (See Figure.) Drillings or turnings from the tensile specimen shall be used to determine the chemical properties.

STAMPING AND MARKING.

Each forging must have heat number and name of manufacturer plainly stamped on one end with figures not less than ⅜ inch and have order number plainly marked with white lead.

INSPECTION.

All forgings must conform to drawings which accompany these specifications, and be free from seams, pipes, and other defects.

Any forgings failing to meet any of the above requirements, or which prove defective on machining, will be rejected.

The above specifications for locomotive forgings are based upon the specifications adopted by the American Society for Testing Materials, with some slight modifications, which, it is believed, will tend to improve the product. The physical test is substantially the same as that recommended above for testing locomotive driving and truck axles, and the same arguments may be used in its favor.

PROPOSED SPECIFICATIONS FOR STEEL BLOOMS AND BILLETS FOR LOCOMOTIVE FORGINGS.

MATERIAL.

Open Hearth Steel.

PHYSICAL REQUIREMENTS.

Grade "A:"

Tensile strength, 70,000 pounds per square inch.
Elongation in two inches, 20 per cent.

Grade "B:"

Tensile strength, 80,000 pounds per square inch.
Elongation in two inches, 17 per cent.

CHEMICAL ANALYSIS.

Grade "A:"

Carbon	0.25 to 0.40	per cent.
Phosphorus, not to exceed	0.06	"
Sulphur, " "	0.06	"
Manganese, " "	0.60	"

Grade "B:"

Carbon	0.35 to 0.50	per cent.
Phosphorus, not to exceed	0.05	"
Sulphur, " "	0.05	"
Manganese, " "	0.60	"

NUMBER OF TESTS.

One test per melt should be required, the test specimen to be cut cold from the bloom, parallel to its axis and half-way between the center and the outside. The standard turned test specimen, one-half inch in diameter and two inches gauge length, shall be used to determine the physical properties. (See Fig. 1.) Drillings or turnings from the tensile specimen shall be used to determine the chemical properties.

STAMPING AND MARKING.

Each bloom or billet must have heat number and manufacturer's name plainly stamped on one end, with stamps not less than ⅜ inch and have order number plainly marked with white lead.

INSPECTION.

Blooms and billets must be free from checks, pipes, and surface defects. Any blooms or billets chipped to a depth greater than one-half inch will be rejected.

Any billet or bloom failing to meet the above requirements will be rejected and held, subject to disposal by manufacturers.

Inspector to have the privilege of taking drillings from the center of the top bloom or billet of the ingot in order to determine the amount of segregation.

Grade "A" is blooms or billets for rod straps and miscellaneous forgings.

Grade "B" is blooms or billets for driving and truck axles, connecting rods, crank pins and guides.

F. H. Clark, *Chairman*,
J. E. Sague,
S. M. Vauclain,
L. R. Pomeroy,
Committee.

Chicago, Illinois, June 6, 1903.

PROPOSED MODIFICATIONS IN THE SPECIFICATIONS FOR STEEL RAILS ADOPTED BY THE AMERICAN RAILWAY ENGINEERING AND MAINTENANCE OF WAY ASSOCIATION IN MARCH, 1903.

WITH INTRODUCTION BY WILLIAM R. WEBSTER, CHAIRMAN.

The differences in the specifications proposed last year by this Committee and those adopted by the American Society for Testing Materials were fully discussed at the Fifth Annual Meeting, June, 1902, and referred back to Committee No. 1 for further consideration.*

Since then four members of this Committee met with a committee of the rail manufacturers in Chicago, and reported at the Annual Convention last March as follows:

"As a result of our interview with the manufacturers yesterday, we found they were very much opposed to giving a drop test on each heat of steel. We would therefore suggest that a drop test on one heat in five be accepted for the present. We do not want to commit the other members of the Committee to this matter, and merely offer it as a suggestion. That is about the only suggestion we have to make on the report submitted last year.

"Our views in regard to the shrinkage clause are unchanged. We have not enough information to suggest anything definite at this time. We want to offer for discussion the matter of a greater height of drop on the heavier section rails than submitted in our report; we offer no change, but merely want the views of the members present, so that there are really only one or two points we offer for discussion.

"The manufacturers said that they wanted us to consider the matter of standard drilling. They thought that was something that would be of benefit to all. The Committee has not that subject before it, but if it is thought advisable to take it up, we will do so."

This report was approved and accepted as a report of progress and the Committee continued.

The Committee has since received the following instructions for this year:

"Drop tests. Shrinkage clause. Confer with Track Committee with regard to standard drilling. Submit revised specifications, if deemed advisable, supplying margined index. Publish October 1. Discussion to close September 1."

* See Proceedings, vol. ii, pp. 23–49.

The committee of rail manufacturers have suggested the following standard drilling for consideration:

All holes 1 inch in diameter.

For 4-hole splice, $2\frac{1}{2}''$–$5''$.

For 6-hole splice, $2\frac{1}{2}''$–$5''$–$6''$.

During the past year proposed specifications were prepared by Mr. Trimble, former Chairman of the Committee, and were submitted to the members for their written opinions. The principal differences between these specifications and those presented at the Atlantic City meeting are:

1. Height of drop for heavier sections.
2. Lengths of rails. Shortest length, 24 feet.
3. Straightening both hot and cold.
4. Inspection.
5. No. 2 rails.

DISCUSSION.

Mr. Job.

ROBERT JOB.—1. As to detection of coarse grain in steel rails by means of drop tests:

(*a*) Our practice has proved beyond any question that the ordinary drop test of weight of 2,000 pounds falling 20 feet upon butts about 4½ feet long and 3 feet between supports, does not cause fracture of coarse-grained rails, 80 pounds and over, excepting when brittleness due to other causes, such as piping, burning of steel, etc., is present.

(*b*) Large microstructure is due to slow, undisturbed cooling from a high temperature, and causes lessened ductility, and lessened strength under impact. Consequently it should be perfectly feasible so to proportion weight and height of drop as to produce fracture if grain exceed a certain size. Since service results (paragraph 4) show that with solid steel resistance to wear—other properties and conditions being equal—increases with decrease of size of grain, it follows that a test so arranged must be of great value as an indication of the service life of steel.

2. As to relation of microstructure to appearance of fractured surfaces:

(*a*) When the fractured surface appears coarse-grained the microstructure is coarse-grained.

(*b*) When the fractured surface appears fine-grained the microstructure may or may not be fine-grained. In other words steel of coarse microstructure may be made to show a fairly fine-grained fracture under certain conditions of fracturing.

(*c*) When the microstructure is fine-grained the fractured surface appears fine-grained.

(*d*) To illustrate the relations existing at given points between appearance of grain in microstructure and upon fractured surfaces when the conditions attending the fractures are identical throughout, we took a steel slab, about 6 inches wide, 1½ inches thick, and 2 feet long, let one end remain in fire just below melting temperature for two hours, the other end being cool. The slab

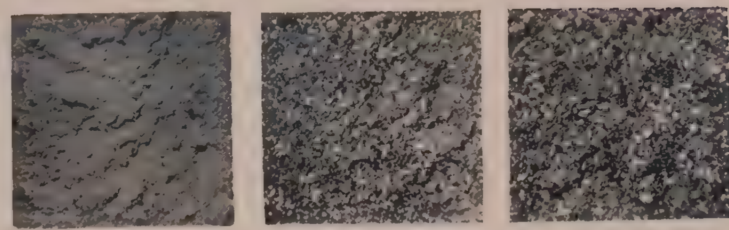


FIG. 1.
Fractures of Steel Bar
Magnified Two Diameters.

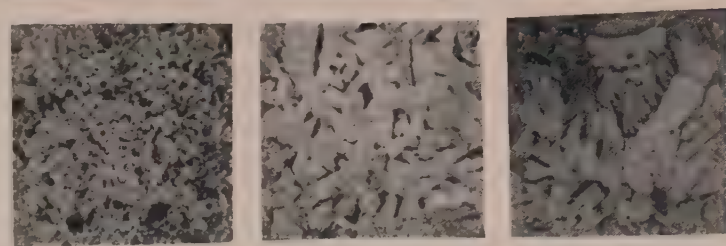
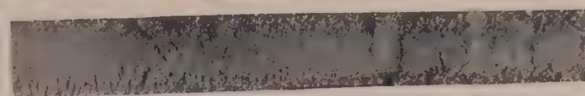


FIG. 2.
Microstructure of Steel Bar
Magnified Fifty Diameters



1. 2. 3.

FIG. 3.
Original Fractured Surface
of Bar.
(One-half size.)

was then removed from the fire and let cool in air, and a slot cut about ¼ inch deep along the slab longitudinally. The slab was fractured longitudinally under the steam hammer and the surface was photographed, one-half size, Pl. II., Fig. 3,* showing gradual change in size of grain from fine to coarse (Metcalf's experiment). Mr. Job.

The fracture of the steel was then photographed (2 diameters), Fig. 1, at points 1, 2 and 3 indicated upon Fig. 3. Microsections were taken from the same points, and appear (50 diameters) in Fig. 2.

It will be seen that under these conditions of fracturing there is a close general relation between the size of grain of the fractured surface as seen by the eye and that shown in the microstructure at corresponding points. It should, however, be noted that when a number of rails from the same rolling are fractured, the surfaces may vary considerably from fine to coarse, although the general microstructure is usually quite constant because the latter is not subject to the varying conditions which attend the taking of different fractures.

The composition of the steel slab follows:

Carbon	0.090
Manganese	0.277
Phosphorus	0.135
Sulphur	0.106

3. As to relations between appearance of fracture and poor service wear.

In most cases rails of fairly solid steel fracturing in service, or giving poor wear, have shown coarse-grained fracture, indicating high finishing temperature. In relatively few cases the fracture has appeared fairly fine-grained, but upon polishing and etching a section, the structure has always appeared coarse unless the poor service was due to low elastic limit, or to seamy condition of the steel, either of which characters precludes proper service irrespective of granular form.

* Acknowledgment is made to the *Engineering News Publishing Company* for the cuts used in this paper.

Mr. Job. 4. As to relations between coarse microstructure and poor wearing qualities of rails in service.

Upon a lot of 75,000 tons of 90-pound rails observed during a period of five years, we have found fifteen times as many fractures in the case of rails having coarse microstructure (Fig. 4) as in those of a much finer form (Fig. 5). We have also invariably found, with good degree of solidity of steel and with other properties and conditions approximately equal, a marked increase in rapidity of wear of steel of the coarse microstructure as compared with that of the finer.

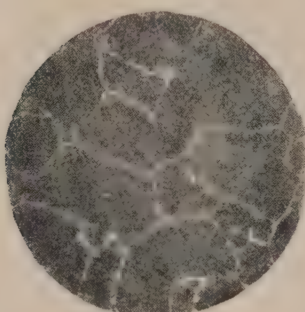


FIG. 4.
Coarse-grained rail, center of head. × 50.

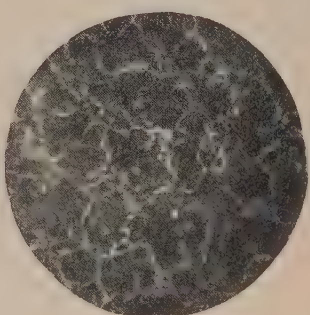


FIG. 5.
Rail, center of head. × 50.

5. As to relation between degree of shrinkage of rails after hot saws, and service life.

(*a*) Rails with shrinkage of 7 inches and over on 30-foot length have showed relatively large number of fractures and relatively rapid wear.

(*b*) Rails with shrinkage of $6\frac{1}{4}$ inches and less on 30-foot length, with rapid rolling and without holding between passes, have showed very largely decreased number of fractures, together with increased capacity for wear when the steel was solid.

6. As to relations between piping of rails and fractures in service and under drop test.

A large majority of the rails fractured in service and under drop test show piping to a considerable extent either directly upon

the fractured surface or else when the cross-section is polished and etched. Mr. Job.

7. As to tests necessary to insure tough, well-wearing rails, we may cite the following:

(*a*) Absence of brittleness is insured in 90-pound rails by drop test of 2,000 pounds falling 23 feet upon rail butts about 4½ feet long, 3 feet between supports, one test being made upon each heat, each test butt being taken from the top of an ingot.

(*b*) Toughness and moderately slow wear, if the steel is solid, is insured by enforcing the following practice, viz.: temperature of ingot or bloom to be such that with rapid rolling and without holding before or in the finishing passes or subsequently, and without artificial cooling after leaving last pass, the distance between hot saws shall not exceed 30 feet 6 inches for a 30-foot rail, or a proportionate distance for other lengths.

(*c*) Solidity of steel can be insured only by careful inspection throughout the process of manufacture, especially as regards cropping.

(*d*) Suitable chemical composition is essential to the best service results. For 90-pound rails we prefer about the following, with the ordinary rolling practice:

Carbon	0.60 to 0.65	per cent.
Phosphorus, below	0.06	"
Sulphur, below	0.07	"
Manganese	0.90 to 1.30	"

P. H. DUDLEY.—During the past year drop tests have been made of the physical properties of steel for rails which were rolled colder than the usual practice. The chemical composition averaged carbon 0.53 per cent., manganese about 1 per cent., silicon, sulphur and phosphorus, 0.06 to 0.07 per cent. The microstructure in the center of the head ranged from 7,000 granulations per square inch to 10,000 incomplete granulations, classed as non-granular. Under drop tests of 40,000 foot-pounds, supports 3-feet centers, the permanent sets ranged from 2.25 to 2.5 inches. Only every fifth heat was tested, the variation in results being marked. The butts were from the middle of the ingot. In the 5 ⅝-inch 80-pound rails, Dudley section, which have not taken a set in the track Mr. Dudley.

Mr. Dudley. under driving-wheel axle loads of 45,000 to 48,000 pounds, their requisite physical properties gave only a permanent set for the drop test mentioned of 1.55 inches. This is considered the standard for that section, having elastic limits of 55,000 to 60,000 pounds. The average speed of the through trains passing over the rails is approximately sixty miles per hour, while maximum speeds of eighty and ninety miles are daily occurrences. A reduction of the elastic limits in the steel for a permanent set of 2.25 inches or more in the colder rolled rails is so much that it is certain that sets will develop in the rails in the track, under service. The chemical composition was adjusted to reduce the permanent sets of the drop test under 2 inches.

The granulations in the microstructure ranged about 6,000 per square inch in the colder rolled rails. The metal was tough, not a single butt breaking under the drop. The rails were undercambered slightly in the straightening presses, and were gagged principally on the base. They finished smooth, without traces of undulations on the head. When the rails were laid in the track, their excellent surface attracted attention at once by observers, and the smooth riding of the coaches in contrast with another brand of rails, rolled cold, out of steel of lower physical properties.

Some of these rails have been made into frogs and switches, for comparisons of wear with other steel of lower grades. Rails rolled of the chemical composition recommended by the Society, and manufactured into frogs and switches, have been in service under heavy traffic, in comparison with frogs and switches made from steel according to the chemical composition I have advocated for some years. The results so far are in favor decidedly of the higher chemical composition and physical properties of the steel, the lower grades of steel rendering only one-half to two-thirds as long service under the same wheel loads.

At the Grand Central Station in New York, where the service on the limited tracks exceeds in heavy tonnage any other terminal station for steam railroads, the frogs and switches made from the high-carbon rails give a service which railroad officials using lower grades of steel can hardly credit. Out of several hundred switch points, which of necessity must be short (15 feet

in length), only four have broken since the 6-inch 100-pound rails were installed in 1895. I am unable to find elsewhere as favorable a record. Mr. Dudley.

In the manufacture of these high-carbon rails, a drop test was made from every heat of steel. The advantages of this, to determine quickly the physical properties of the steel, and its aid in the manufacture, seem to be practically unknown. They can be made so quickly, accurately, and without preparation of the specimens that the manufacture of the steel can be followed within five to six hours after its conversion. The permanent set of the specimens is the measure of the combined mechanical and physical properties of the section. The first are known, which enables the second to be determined approximately in a moment, for the purposes of manufacture and inspection, for the methods should be quick, and sufficiently accurate to follow the product, and not restrict the output.

SPECIFICATIONS FOR BOILER PLATE, RIVET STEEL, STEEL CASTINGS AND STEEL FORGINGS.

Recommended by a Committee of the American Society of Mechanical Engineers, H. W. Spangler, Chairman, in June, 1903.*

The Committee to which was referred the question of specifications for boiler plate, rivet steel, steel castings and steel forgings reports that it has used the specifications prepared by the enlarged American Branch of Committee No. 1 of the International Association for Testing Materials,† of which Mr. Wm. R. Webster is Chairman, as the basis of its work, and the changes hereafter noted are recommended in these specifications.

1. That the maximum sulphur in flange or boiler steel be reduced from 0.05 to 0.04.

2. That the tensile strength be specified as stated in the table with an allowable variation of 5,000 pounds. That fire-box steel be specified at 55,000 pounds instead of 57,000 pounds per square inch. That the determination of the yield point for ordinary grades be omitted.

3. The tensile strength of castings has been modified, the specified value desired being stated, and the variation, 5,000 pounds, being allowed. The values, as recommended by Committee No. 1, and by this Committee, are as follows:—

	Com. No. 1's Minimum.	Recommended by Committee.
Soft	60,000	60,000 ± 5,000
Medium	70,000	70,000 ± 5,000
Hard	85,000	80,000 ± 5,000

4. The elongation in 8 inches is stated instead of in 2 inches, and an increase in elongation of 25 per cent. is called for on the 2-inch specimen.

For a 2-inch specimen from castings the corresponding elongations are:

	Com. No. 1.	Recommended by this Committee.
Soft	22 per cent.	20 per cent.
Medium	18 per cent.	17.5 per cent.
Hard	15 per cent.	15 per cent.

5. That the 8-inch specimen be made the standard specimen and the 2-inch be used only when it is inconvenient to use the 8-inch.

* This report was made, subject to revision, by a committee consisting of Messrs. H. W. Spangler, Edwin S. Cramp, William Kent, George S. Morison and Arthur M. Waitt. It was reported to the Society at the Delaware Water Gap meeting by Mr. William Kent.

† Now designated Committee "A" of the American Society for Testing Materials, on "Standard Specifications for Iron and Steel."

6. That nickel-steel forgings and oil-tempered forgings be not included in this specification, because the present state of the art does not warrant general specifications being drawn for these materials.

7. That for soft or low carbon steel forgings the chemical requirements be not over 0.06 phosphorus, and 0.05 sulphur, instead of 0.10 phosphorus and 0.10 carbon.

8. That for "carbon steel not annealed" the term "medium steel" be used, and that the sulphur be reduced from 0.06 to 0.05 per cent.

9. That, wherever it is desirable that the elastic limit be determined, an extensometer be used, and that the elastic limit be taken as "that point at which the elongation in 8 inches per 1,000 pounds of added stress per square inch first exceeds four ten-thousandths of an inch."*

10. The remainder of the specifications of Committee No. 1 are recommended for adoption, and are here re-arranged.

STANDARD SPECIFICATIONS FOR STEEL BOILER PLATE, RIVETS, CASTINGS AND FORGINGS.

Process of Manufacture.

Boiler Plate and Rivet Steel shall be made by the open-hearth process.

Castings and Forgings are to be made by the open-hearth, crucible, or Bessemer process.

Castings are to be annealed or unannealed as specified.

Tensile Tests.

Test Piece—The standard test specimen shall be eight inches (8″) gaged length. The standard shape is shown in Fig. 1.†

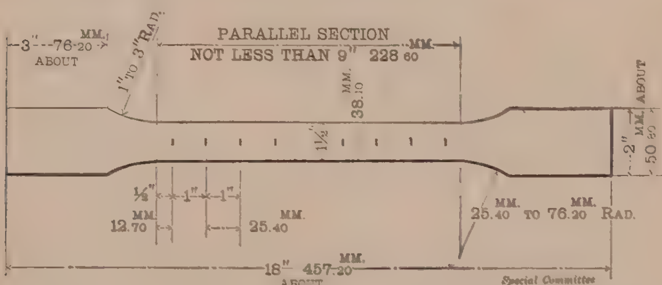


FIG. 1.

Width of specimen along the parallel section shall be 1½ inches, whenever possible.

Thickness of specimen shall be ½-inch or over, whenever possible.

* The "apparent elastic limit," suggested by Prof. J. B. Johnson and re-stated by Kent in *Transactions of Mining Engineers*, 1903.

† Acknowledgment is made to the American Society of Mechanical Engineers for the cuts used in this paper.

Plates—Two opposite sides shall be the rolled surfaces if not over ¾-inch thick.

Rivets—Rivet rounds and small rolled bars shall be tested full-size as rolled.

Castings and Forgings—Specimen may be planed parallel-sided or turned parallel for not less than 9 inches in length, the smallest dimension being ½-inch, if possible.

When it is inconvenient to use the standard test specimen the specimen may be made as shown in Fig. 2. In every such specimen the elongation in two inches will be 25 per cent. greater than that specified for the standard specimen.

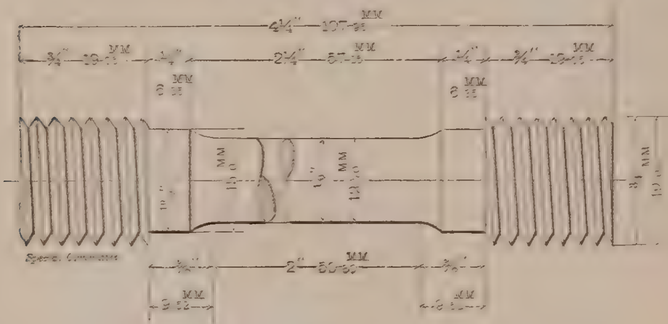


FIG. 2.

Number of Test Specimens.

If a tensile specimen develops flaws or breaks outside the middle third of its gaged length, another may be substituted.

Plates—One from each plate as it is rolled.

Rivet Rounds—Two from each melt.

Castings and Forgings—Depending upon the character and importance of the piece.

Location of Test Specimens.

Castings—A test piece shall be cut cold from a coupon to be molded and cast on some portion of one or more castings from each melt or blow, or from the sink-heads (in case heads of sufficient size are used). The coupon or sink-head must receive the same treatment as the casting or castings before the specimen is cut out, and before the coupon or sink-head is removed from the casting.

Forgings—The test specimen shall be cut cold from the forging or full-sized prolongation of the same parallel to the axis of the forging and half-way between the center and outside, the specimens to be longitudinal—*i.e.*, the length of the specimen to correspond with the direction in which the metal is most drawn out or worked. When forgings have large ends or collars, the test specimens shall be taken from a prolongation of the same diameter or section as that of the forging back of the large end of the collar. In the case of hollow-shafting, either forged

or bored, the specimen shall be taken within the finished section prolonged halfway between the inner and outer surface of the wall of the forging.

Bending Tests.

Bending tests may be made either by pressure or by blows.

Cold-bending tests are to be made on the material in the condition in which it is to be used. For a quenched bending test the specimen shall be heated to a light cherry-red as seen in the dark, and quenched in water, the temperature of which is between 80° and 90° Fahrenheit.

Test Specimen.

Plates—One and one-half inches wide, and if ¾-inch or less in thickness with opposite faces rolled. If over ¾-inch thick, specimen may be reduced to ½-inch. Edges are to be milled or planed.

Rivet Rounds—Tested full-size as rolled.

Castings and Forgings—Specimen one inch by one-half inch.

Number of Test Specimens.

Plates—One cold-bending and one quenched-bending specimen from each plate as it is rolled.

Rivet Rounds—Two cold-bending and two quenched-bending specimens for each melt.

Location of Specimen.

Castings and Forgings—As specified for tension specimen.

Chemical Analysis.

Turnings from tensile specimen, drillings from tensile or bending specimen or drillings from small test ingot may be used for chemical analysis.

For locomotive fire-box steel check, analysis may be required from the tensile specimen of each plate as rolled.

Drop Test.

A test to destruction may be substituted for the tensile test, in the case of small or unimportant castings, by selecting three castings from a lot. This test shall show the material to be ductile and free from injurious defects, and suitable for the purposes intended. A lot shall consist of all castings from the same melt or blow, annealed in the same furnace charge.

Percussion Test.

Large castings are to be suspended and hammered all over. No cracks, flaws defects, nor weakness shall appear after such treatment.

Homogeneity Test for Fire-box Steel.

A sample taken from a broken tensile test specimen, shall not show any single seam or cavity more than one-fourth inch ($\frac{1}{4}''$) long in either of the three fractures obtained as described below.

A portion of the broken tensile specimen is either nicked with a chisel or grooved on a machine, transversely about a sixteenth of an inch ($\frac{1}{16}''$) deep, in three places about two inches ($2''$) apart. The first groove should be made on one side, two inches ($2''$) from the square end of the specimen; the second, two inches ($2''$) from it on the opposite side; and the third, two inches ($2''$) from the last, and on the opposite side from it. The test specimen is then put in a vice, with the first groove about a quarter of an inch ($\frac{1}{4}''$) above the jaws, care being taken to hold it firmly. The projecting end of the test specimen is then broken off by means of a hammer, a number of light blows being used, and the bending being away from the groove. The specimen is broken by the other two grooves in the same way. The object of this treatment is to open and render visible to the eye any seams due to failure to weld up, or to foreign interposed matter, or cavities due to gas bubbles in the ingot. After rupture, one side of each fracture is examined, a pocket-lens being used if necessary, and the length of the seams and cavities is determined.

Branding.

Every finished piece of steel plate shall be stamped with the melt-number, and each plate, casting or forging and the coupon or test specimen cut from it, shall be stamped with a separate identifying mark or number. Rivet steel may be shipped in bundles securely wired together with the melt number on a metal tag attached.

Variation in Weight.

The variation in cross-section or weight of more than $2\frac{1}{2}$ per cent. from that specified will be sufficient cause for rejection, except in the case of sheared plates, which will be covered by the following permissible variations:

Plates $12\frac{1}{2}$ pounds per square foot or heavier, up to 100 inches wide, when ordered to weight, shall not average more than $2\frac{1}{2}$ per cent. variation above or $2\frac{1}{2}$ per cent. below the theoretical weight; when 100 inches wide and over 5 per cent. above or 5 per cent. below the theoretical weight.

Plates under $12\frac{1}{2}$ pounds per square foot, when ordered to weight, shall not average a greater variation than the following:

Up to 75 inches wide, $2\frac{1}{2}$ per cent. above or $2\frac{1}{2}$ per cent. below the theoretical weight; 75 inches wide up to 100 inches wide, 5 per cent. above or 3 per cent. below the theoretical weight; when 100 inches wide and over 10 per cent. above or 3 per cent. below the theoretical weight.

For all plates ordered to gage, there will be permitted an average excess of weight over that corresponding to the dimensions on the order equal in amount to that specified in the following table:

TABLE OF ALLOWANCES FOR OVERWEIGHT FOR RECTANGULAR PLATES WHEN ORDERED TO GAGE.

Plates will be considered up to gage if measuring not over $\frac{1}{100}$-inch less than the ordered gage.

The weight of 1 cubic inch of rolled steel is assumed to be 0.2833 pound.

Plates $\frac{1}{4}$-inch and over in Thickness.

Thickness of Plate. Inch.	Width of Plate. Up to 75 inches. Per cent.	75 to 100 inches. Per cent.	Over 100 inches. Per cent.
$\frac{1}{4}$	10	14	18
$\frac{5}{16}$	8	12	16
$\frac{3}{8}$	7	10	13
$\frac{7}{16}$	6	8	10
$\frac{1}{2}$	5	7	9
$\frac{9}{16}$	$4\frac{1}{2}$	$6\frac{1}{2}$	$8\frac{1}{2}$
$\frac{5}{8}$	4	6	8
Over $\frac{5}{8}$	$3\frac{1}{2}$	5	$6\frac{1}{2}$

Plates under $\frac{1}{4}$-inch in Thickness.

Thickness of Plate. Inch.	Width of Plate. Up to 50 inches. Per cent.	50 inches and above. Per cent.
$\frac{1}{8}$ up to $\frac{5}{32}$	10	15
$\frac{5}{32}$ " $\frac{3}{16}$	$8\frac{1}{2}$	$12\frac{1}{2}$
$\frac{3}{16}$ " $\frac{1}{4}$	7	10

Finish.

All material must have workmanlike finish.

Plates must be free from injurious surface defects and laminations.

Castings must be true to pattern, free from blemish, flaws or shrinkage cracks. Bearing surfaces shall be solid and no porosity shall be allowed in positions where the resistance and value of the castings for the purpose intended will be seriously affected thereby.

Forgings must be free from cracks, flaws, seams or other injurious imperfections, and must conform to dimensions.

Inspection.

The inspector representing the purchaser shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

Respectfully submitted,

H. W. SPANGLER, *Chairman.*

	CHEMICAL PROPERTIES.			PHYSICAL PROPERTIES.			BENDING.	
STEEL.	Phosphorus (not over), per cent.	Sulphur (not over), per cent.	Manganese, per cent.	Tensile strength, lbs. per sq. in. (Allowable variation, ± 5,000 lbs.)	Elongation in 8 in., per cent.	Contraction of area, per cent.	Around a diameter of—	Through —degrees.
BOILER PLATE & RIVET:								
Extra soft...	0.04	0.04	0.30 to 0.50	60,000	28†	...	Flat.	180
Fire box..	Acid, 0.04 Basic, 0.03	0.04	0.30 to 0.50	55,000	26†	...	Flat.	180
Flange or boiler...	Acid, 0.06 Basic, 0.04	0.04	0.30 to 0.60	60,000	25†	...	Flat.	180
FORGINGS:								
Soft........	0.06	0.05	....	60,000	22	35	½″	180
Medium....	0.06	0.05	....	70,000	16	30	1½″	180
High.......	0.04	0.04	....	80,000*	18	35	1″	180
CASTINGS. (When physical requirements are not specified, carbon must be less than 40 per cent, and phosphorus less than 0.08 per cent.):								
Soft........	0.05	0.05	....	60,000	16	30	1″	120
Medium....	0.05	0.05	....	70,000	14	25	1″	90
Hard.......	0.05	0.05	....	80,000	12	20	....	....

* For carbon steel, to be annealed and having no diameter nor thickness greater than 10 inches, allow a reduction of 1,000 pounds for each additional inch in diameter or in thickness of section.

† For material over $\frac{3}{4}$-inch thick deduct 1 per cent. for each $\frac{1}{4}$-inch excess. For material under $\frac{5}{16}$-inch thick deduct $2\frac{1}{2}$ per cent. for each $\frac{1}{16}$-inch decrease.

DISCUSSION.

William Kent.—The committee appointed by the American Society of Mechanical Engineers to prepare these specifications consisted of Messrs. H. W. Spangler, Edwin S. Cramp, George S. Morison, Arthur M. Waitt, and myself, and our work is chiefly a matter of suggestion to the committees of this Society and not in any way final. With regard to the recommendation concerning the yield-point, we refer to the clause in the specifications adopted by this Society, which states that the elastic limit shall not be less than one-half of the ultimate strength. It has become the custom to use this specification, with the result that no steel is ever rejected on account of the elastic limit, that is to say, all steel that would pass the specifications as to tensile strength and elongation would necessarily very easily pass the specification as to elastic limit, and therefore we left this out. The American Railway Engineering and Maintenance of Way Association has done the same thing in its recently adopted specifications for iron and steel structures. Mr. Kent.

William R. Webster.—The specifications adopted by this Society represent the result of a great deal of careful study during the last three or four years, and before making any changes in these specifications we should be certain that there are good and sufficient reasons for doing so. Other societies and committees have been considering our specifications and are now presenting to us the results of their study. This will give us opportunities of conferring with them as to the various changes proposed. We may convince them that these changes are not desirable. On the other hand, they may convince us that they are. This Society should consider itself a sort of clearing-house in which such matters may be fully discussed and settled. Mr. Webster.

The President.—One point has occurred to me on which I should like to say a word, namely, that all our studies of the use of metal subjected more or less to stress is leading us to the idea The President.

The President.

that rather harder steel is desirable. In our latest revision of our boiler-plate specifications the tensile strength and the carbon of the fire-box steel was increased. Our former specifications were from 50,000 to 60,000 pounds tensile strength, and the carbon about 0.12 to 0.14 per cent. Our present specifications are from 55,000 to 65,000 pounds tensile strength, with a minimum of 0.15 per cent. carbon, and a maximum of 0.25 per cent. carbon. Again, the same thing can be said with regard to axles. The original axles were about 65,000 pounds tensile strength with carbon of from 0.20 to 0.28 per cent. At present the axles are from 72,000 to 75,000 pounds tensile strength, with a minimum of 0.35 per cent. carbon, and even this strength in axles does not satisfy us. We want a harder steel than we are at present getting.

Mr. Kent.

MR. KENT.—With regard to what the President has said about the fire-box steel, the specification for fire-box steel came originally from the Pennsylvania Railroad Company about twenty years ago. The very name of fire-box steel was due to the fact that the Pennsylvania Railroad Company wanted a softer steel than other people were willing to provide for boilers. I understand the steel they now use is the same as is called flange or boiler steel in the Committee's report, that is, of 60,000 pounds average tensile strength. In the old days it was necessary to get an exceedingly soft steel for fire-box steel for the Pennsylvania Railroad for the reason that with harder steel the fire-box would crack. Now it seems the makers have gotten over that trouble of cracking fire-boxes because they allow less phosphorus, and for that reason they can have more carbon and a harder steel. The cracking used to be such a serious thing that users were willing to stand troubles in abrasion and with staybolts rather than submit to cracking.

Mr. Huston.

CHARLES L. HUSTON.—From our observations on material which had given out in locomotive fire-box service, we concluded that a harder grade of steel than was generally used was desirable under certain conditions. We have noticed a tendency to bulging inward between staybolts owing to the material being too soft to resist the pressure. The plates sometimes looked almost like tufted cushions. The effect of that, with variations of pressure in the boiler, was to start a series of star like cracks from staybolt

to staybolt. This, together with other considerations, lead us to conclude that a little harder steel, say of about 60,000 pounds, was generally advisable, and we announced this in a little handbook that our company put out. I am glad to see that this is being corroborated by actual experience. Mr. Huston.

This does not, however, apply to flanged work in general, nor to marine and other boilers fired internally. Such boilers, in which the material is thicker, would be better able to resist the staybolt action than locomotive boilers.

The tendency to make a sort of omnibus specification covering shell plates and flanging work in general does not seem to me a very wise thing. If the steel is a little softer it can be more easily flanged by hand-work. Of course, some large establishments are equipped with hydraulic presses and a large number of standard dies, so that they can do a good deal of their work by power. In that case the softness of the steel is not so essential; but where flanging is done by hand-work, or where it would be practically impossible to keep a sufficient number of dies on hand for the variety of shapes, it is desirable for the steel to be a little softer. It seems to me that such material would meet other requirements just as well in many cases. As plate manufacturers, we should like to see plates used having a tensile strength as low as 50,000 pounds. In all our observation on material of that character used for the purposes just named, we have never known of any failure or complaint and we advocate the continuance of that practice.

The tendency among engineers to restrict sulphur to more and more narrow limits does not seem to me to be sufficiently justified. I have never been able to obtain any evidence that sulphur within reasonable limits, say to even seven or eight points, was any detriment to mild steel when cold, only affecting the workability of the metal when hot; so that for material to be worked cold the buyer has no need to restrict sulphur. By doing so he throws an unnecessary burden and expense on the manufacturer. Such excessive requirements are especially severe on Eastern manufacturers, and, by tending to restrict competition, are against the interest of the consumer.

Although the action has already been taken, and it is probably too late to discuss the question of a single grade of structural steel,

Mr. Huston. yet I want to say that a 10,000 pounds limit—55,000 to 65,000 pounds tensile strength—is a little harder on some of the manufacturers of plate steel. Now, in structural steel, for which one size of ingots is used for practically everything, the ingots for the different grades can be sorted; but in plate steel, even where it passes through a slabbing mill, the ingots are made either small or large, according to whether the material is to be thin or thick, or small or large pieces are to be rolled; so that material which is made, say in suitable-sized ingots, for thinner plates, if it should be a little high in carbon, would be rendered useless for thicker plates, because the ingots made for the small pieces are too small for large pieces. At the same time, the carbon being too high, it cannot be used for the smaller pieces. Such requirements are really restricting the freedom of competition of some classes of manufacturers. At the same time I want to encourage everything that will tend toward good material; because then those who make good material will get better consideration.

Mr. Kinkead. J. C. KINKEAD.—Regarding the bulging of fire-box plate between staybolts, referred to by Mr. Huston, a member of this Society made a rather interesting test by taking a plate about twelve inches square, heating it red hot, suspending it by one corner, and then squirting cold water on it. By repeated applications the plate was drawn out somewhat in the shape of a Panama hat. Almost everyone when asked which way the plate had bent thought it had bent away from the water, on account of the contraction on that side; but the fact is it had bent toward the stream.

Another member of this Society rigged up a sort of fire-box by taking a boiler plate, and with the usual arrangement of staybolts fastened a fire-box plate to it. The sheets, which were about fourteen or sixteen inches square, were put in the usual position. This was heated to a red heat and cold water was turned against the fire-box plate on the inside, just as would be done in washing out a boiler. It did not take many applications of water to bulge the plate, as is often noticed in fire-box plates after they have been in service, and cracks connecting the staybolts also developed. The question arises whether this is due to the quality of the steel or to the treatment that the steel receives in the boilers. The gentleman who made this test inclined to the latter view.

M. H. Wickhorst.—I have had to investigate a good many failures of fire-boxes, and they can be divided into two distinct classes. First, we have corrugated, bulged-out fire-box sheets. In the "wild West" we call them tumored. This condition is always accompanied by cracks radiating out from the staybolts. Such fire-boxes do not give any trouble by sudden failure, but there is a gradual, detailed failure. The cracks continue to widen out until they allow water to escape and have to be plugged up. On the other hand, we have failures of fire-boxes by sudden rupture, in which the rest of the sheet is apparently in good condition. Chemical analysis shows that the detailed failures have always been with a low-carbon material, that is, below or possibly a little above 0.15 per cent.; while the other failures have practically always occurred with a harder material, containing from about 0.25 per cent. to 0.35 per cent. carbon. We seem to be confined, therefore, to a material of the grade generally used, containing between 0.15 per cent. and 0.25 per cent. carbon, and having an average tensile strength of about 60,000 pounds per square inch. It seems to me that when we shall have learned to take care of engines, and particularly fire-boxes, intelligently, to eliminate scale and mud, to wash and blow out properly, to provide efficient circulation, etc., we shall probably be able to use a harder material with entire safety. At present we dare not go above about 0.25 per cent. carbon, and on the Chicago, Burlington and Quincy Railway we have been trying to adhere pretty closely to a steel of about 60,000 pounds' tensile strength. I should not recommend a steel of as low an average as 55,000 pounds. Mr. Wickhorst.

Joseph Royal.—On the Imperial Railroad of Japan we had a number of locomotives that failed, owing to the cracking of the side-sheets and flanges. These failures fell heavily on the manufacturers of the locomotives, since they were struck off the approved list of manufacturers. In order to locate the trouble, they went to the expense of having a damaged fire-box cut out and shipped to America, together with samples of the water used. Mr. Royal.

A committee, consisting of an expert consulting engineer, an expert chemist, representatives from the makers of the steel, from the builders of the engines and from the consulting engineer and inspector, were appointed to impartially consider the matter, and,

Mr. Boyd. if possible, to determine the cause of the failure. Physical tests and analyses were made from pieces cut from the damaged fire-box, and numerous inspections and photographs were made to aid in the determination of the cause. About thirty gallons of water, taken from the different divisions of the road, and shipped over in sample demijohns, were also analyzed.

The fire-box sheets had pitted on the inside in numerous places, not only around and near the staybolts, but between the staybolts in large patches, an inch and a quarter in diameter and one-quarter of an inch deep in some cases, and the fire boxes failed in longitudinal cracks and on the flanges.

We were unable, however, to determine the actual cause, and the matter was referred to the expert consulting engineer. His report to the committee was, in brief, that the failure was probably due to the water and bad handling of the boxes.

This resulted in the adoption on the part of the Imperial Government Railroad of a specification calling for a tensile strength of 58,000 to 64,000 pounds per square inch for fire-box steel, and requiring all flanges, except the throat sheet, to be made in one heat and one operation, with a hydraulic power flanging press. That feature is one that might well be considered by our Committee on Specifications, as it is a very recent requirement of foreign specifications and one that our manufacturers are not fully equipped to meet. I know of one instance where the specifications required the sheets to be flanged in one heat and one operation with a power press; and the persons who received the contract were unable to comply with the same, and we were obliged to permit them to flange in the old way.

Mr. Parks. W. M. PARKS.—The Bureau of Steam Engineering of the Navy Department requires, for the flange part of the old fashioned tank boilers, plates of 60,000 to 70,000 pounds tensile strength. For the new water-tube boilers, with drums, say thirty eight to forty-two inches in diameter, the same material is required for the flanged ends. There we have to flange not only to join the cylindrical part of the drum, but also to form the seating of the man-hole plates. This double flanging is quite a severe test for the material.

THE MANUFACTURERS' STANDARD SPECIFICATIONS.

As Revised February 6, 1903, *and Their Comparison with Other Recent Prominent Specifications.*

By Albert Ladd Colby.

The first successful effort in America to standardize specifications for steel was made in August, 1895, by the Association of American Steel Manufacturers, a technical organization formed to discuss matters pertaining to the manufacture and use of steel. These specifications the Steel Association revised on July 17, 1896, and again on October 23, 1896. They included specifications for structural steel for buildings, bridges, and ships, special open-hearth plate and rivet steel, and structural cast iron.

Although these specifications were at first criticised and referred to by the technical press and by some engineers as "Manufacturers' Standards," they nevertheless grew in favor among consumers when it was found that just as good steel was furnished as when using specifications containing many additional tests and requirements unnecessary in the present state of the art of making steel. The customer also soon appreciated that these *standard* specifications secured closer competition and more prompt deliveries.

At the meeting of the Association of American Steel Manufacturers, held in Pittsburg on February 6, 1903, the practical value of these standard specifications was commented on, and the advisability of their revision was discussed. The then recent suggestion of Mr. Snow's Committee on Specifications for Iron and Steel Structures of the American Railway Engineering and Maintenance of Way Association, as to the advisability of adopting one grade of rolled steel for all structural purposes, except rivets, was seriously considered, as well as their suggestion that the percentage of elongation be made a factor of the ultimate strength. Attention was called to the fact that if a general revision of the Manufacturers' Standard Specifications was contemplated it should include the Revised Schedule of Standard Permissible

Variations in the Weight of Sheared Plates, as revised by the Steel Association on April 19, 1902. The detailed discussion of each paragraph of the Manufacturers' Standard Specifications of October 23, 1896, was followed by the appointment of a committee representing all interests, who were instructed to incorporate the changes suggested at the meeting and thoroughly revise the Manufacturers' Standard Specifications. Their report has since been submitted and approved by a letter ballot of the following steel companies, members of the Association of American Steel Manufacturers:

American Iron and Steel Manufacturing Company, American Steel and Wire Company, American Steel Hoop Company, Bethlehem Steel Company, Cambria Steel Company, Carbon Steel Company, Carnegie Steel Company, Central Iron and Steel Company, The Colorado Fuel and Iron Company, Crucible Steel Company of America, The Diamond State Steel Company, Glasgow Iron Company, Illinois Steel Company, Inland Steel Company, Jones & Laughlin Steel Company, Lackawanna Steel Company, The Lorain Steel Company, Lukens Iron and Steel Company, Maryland Steel Company, National Steel Company, National Tube Company, The Otis Steel Company, Ltd., Passaic Steel Company, The Pennsylvania Steel Company, Pittsburg Forge and Iron Company, Reading Iron Company, Republic Iron and Steel Company, A. & P. Roberts Company, Shelby Steel Tube Company, The Standard Steel Works, Tennessee Coal, Iron and Railroad Company, Tidewater Steel Company, Worth Brothers Company.

The revised "Manufacturers' Standard Specifications" recommend one grade of steel for railway bridges, except rivets, of a tensile strength of 55,000 to 65,000 pounds, and a steel of this same range in tensile strength for flange or boiler steel.

In structural steel they make the required elongation for usual thicknesses a factor of the ultimate strength, determined by dividing 1,400,000 by the ultimate strength. The Railway Committee use 1,500,000. For a range in tensile of 55,000 to 65,000 the manufacturers therefore specify 25.5 per cent. and 21.5 per cent., respectively, whereas the Railway Committee require 27.3 per cent. and 23.1 per cent.

The prompt adoption by the Steel Manufacturers' Association of the recommendations of the Railway Committee, even before the latter Committee had submitted its report to its Association, forms an important practical advance in the standardization of steel specifications. It means that in place of the existing range of from 52,000 to 70,000 pounds, the manufacturers will now be required to furnish all steel for general structural purposes within 55,000 to 65,000 pounds, a range of only 10,000 pounds per square inch. This will necessitate more care in both melting and rolling, and will result in a more uniform product than furnished under existing specifications.

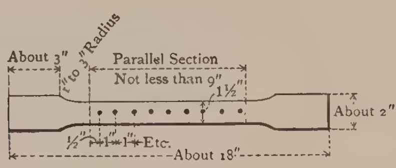
Before the Railway Committee had reached the above decision, the American Bridge Company had issued specifications for structural steel for buildings, calling for a steel of 55,000 to 65,000 pounds, with 24 per cent. elongation, which values have since been adopted by the Bureau of Docks and Yards of the United States Navy. The writer has been informed by Mr. C. C. Schneider, of the American Bridge Company, who is also a member of the Railway Committee, that his company heartily indorses the action of the Railway Committee, in adopting a steel of this same range in tensile strength for railway bridges, but that until pending questions in reference to unit stress and the impact formula, etc., are decided, his company will not revise their present specifications for railway bridges, but that when such revision is made, a steel of 55,000 to 65,000 pounds will be specified.

Table I. gives a comparison of the physical and chemical properties called for in six important specifications for structural steels, including the revised specifications just issued by the Association of American Steel Manufacturers, their former specifications of October 23, 1896, the standard specifications adopted by the American Society for Testing Materials, on August 10, 1901, the American Railway Engineering and Maintenance of Way Association specifications of March, 1903, and the American Bridge Company's specifications now in force.

The requirements other than the chemical and physical properties included in the specifications were not included in the table, as they can be more conveniently compared as follows:

Form of Test Specimens.—The first five specifications included in Table I. specify the form of test specimen for determining the tensile tests of sheared plates, shown in the accompanying cut, allow parallel specimens when necessary, and specify that rivet rounds shall be tested of full size as rolled. The American Bridge Company's specifications state that the tensile strength, etc., "shall be determined from a standard test piece cut from the finished material, of at least ½-inch square section."

Marking, Finish, and Annealed Material.—The first five specifications state that the finished material must be stamped with the heat number and that it shall be "free from injurious seams, flaws, or cracks and have a workmanlike finish." The Railway Specifications add after the word "cracks" the words "or defective edges." The American Bridge Company specify that the "finished bars, plates, and shapes must be free from injurious seams, flaws, or cracks, and have a clean, smooth finish."



All six specifications state that if the finished material is to be annealed, the test specimen must receive the same treatment before testing.

Allowable Variations in Weight.—The Railway Committee have adopted the standard permissible variations in the weight of sheared plates, as revised by the Association of American Steel Manufacturers on April 19, 1902, and which is given in full in the text of the revised Manufacturers' Standard Specifications printed herewith.

The two A. S. T. M. Standard Specifications contain an older edition of this same table. The American Bridge Company specification simply states that "A variation in cross-section or weight of rolled material of more than 2½ per cent. from that specified may be cause for rejection."

TABLE I.—COMPARISON OF THE PHYSICAL AND C

	1. Association of American Steel Manufacturers, February 6, 1903.	2. Association of American Steel Manufacturers, October 23, 1896.	Standard Sp
PHYSICAL PROPERTIES.	STRUCTURAL STEEL.	STRUCTURAL STEEL.	STRUCTURAL STE
Rivet Steel:			
Ultimate strength	48,000 to 58,000	48,000 to 58,000	50,000 to 60,000
Elastic limit	½ ultimate strength	½ ultimate strength	½ ultimate streng
Elongation in 8″	$\frac{1,400,000}{\text{Ultimate strength}}$	26 %	26 %
Bending test	180° flat	180° flat	180° flat
Steel for Railway Bridges:		Called "Soft Steal."	
Ultimate strength	55,000 to 65,000	52,000 to 62,000	
Elastic limit	½ ultimate strength	½ ultimate strength	
Elongation in 8″	$\frac{1,400,000}{\text{Ultimate strength}}$	25 %	
Bending test	180° over diameter = thickness	180° flat	
Medium Steel:			
Ultimate strength	60,000 to 70,000	60,000 to 70,000	60,000 to 70,000
Elastic limit	½ ultimate strength	½ ultimate strength	½ ultimate streng
Elongation in 8″	$\frac{1,400,000}{\text{Ultimate strength}}$	22 %	22 %
Bending test	180° over diameter = thickness	180° over diameter = thickness	180° over diamete
CHEMICAL PROPERTIES.			
Steel for buildings, train sheds, highway bridges, and similar structures	Not over 0.10 % phosphorus	Not over 0.10 % phosphorus	Not over 0.10 % p
Steel for railway bridges	Not over 0.08 % phosphorus	Not over 0.08 % phosphorus	
Rivet steel	Not over 0.08 % phosphorus	Not over 0.08 % phosphorus	

...ICAL PROPERTIES SPECIFIED FOR STRUCTURAL STEEL.

	4. ...ations, American Society for Testing Materials, August 10, 1901.		5. American Railway Engineering and Maintenance of Way Association, March, 1903.	6. American Bridge Company Specification now in force.
	...r BUILDINGS.	STRUCTURAL STEEL FOR BRIDGES AND SHIPS.	MATERIAL FOR STEEL STRUCTURES.	STRUCTURAL STEEL FOR BUILDINGS.
	. . .	50,000 to 60,000	45,000 to 55,000	48,000 to 58,000.
	. . .	½ ultimate strength	. . . . .	½ ultimate strength.
	. . .	26 %	$\frac{1,500,000}{\text{Ultimate strength}}$	26 %.
	. . .	180° flat	180° flat	180° flat.
		Called "Soft Steel."	Called "Structural Steel."	
	. . .	52,000 to 62,000	55,000 to 65,000.	
	. . .	½ ultimate strength		
	. . .	25 %	$\frac{1,500,000}{\text{Ultimate strength.}}$	
	. . .	180° flat	180° flat.	
				Called "Structural Steel for Buildings."
	. . .	60,000 to 70,000	. . . . .	55,000 to 65,000.
	. . .	½ ultimate strength	. . . . .	½ ultimate strength.
	. . .	22 %	. . . . .	24 %.
	...thickness.	180° over diameter = thickness.	. . . . .	180° over diameter = thickness.
	...horus . .	. . .	. . . . .	If acid, not over 0.08 % phosphorus. If basic, not over 0.06 % phosphorus.
	. . .	If acid, not over 0.08 % phosphorus If basic, not over 0.06 % phosphorus Not over 0.06 % sulphur	If acid, not over 0.08 % phosphorus. If basic, not over 0.04 % phosphorus. Not over 0.05 % sulphur.	
	. . .	If acid, not over 0.08 % phosphorus If basic, not over 0.06 % phosphorus Not over 0.06 % sulphur	Not over 0.04 % phosphorus Not over 0.04 % sulphur	If acid, not over 0.08 % phosphorus If basic, not over 0.06 % phosphorus.

Tests of Full-sized Eye-bars.—It will be noticed that the revised Manufacturers' Standard Specifications printed herewith omit the paragraph contained in the former edition of October 23, 1896, covering specified requirements on full-sized tests of steel eye-bars. The Manufacturers' Committee purposely omitted this paragraph in revising the specifications, because they considered it an injustice to hold the steel-maker responsible after his eye-bar material had been forged and annealed at the bridge shop.

Samples for Chemical Analysis.—The Railway Committee requires the manufacturer to furnish his analysis on drillings from the test ingot taken when pouring each melt of steel. They provide that check analyses shall be made from finished material if called for, in which case an excess of 25 per cent. above the required limits will be allowed. This is fair to both interests *if* the check analyses are made on the tensile test specimens, but if the inspector has the right to take his sample at any position from the plate, for instance drillings from the central top part of a plate coming from the top part of an ingot, a higher variation in phosphorus, and especially in sulphur, than 25 per cent. from the heat analysis might be found.

Open-hearth Plate and Rivet Steel.—In Table II. a comparison is given of the physical and chemical properties specified for special open-hearth plate and rivet steel, including extra soft steel, fire-box steel, flange or boiler steel, and boiler rivet steel.

For these steels the table shows a comparison of the two editions of the Specifications of the Steel Manufacturers, with the A. S. T. M. Standard Specifications of August 10, 1901.

The chief point to be noted in this comparison is that the steel manufacturers have agreed on a steel for boilers of the same range in ultimate strength, 55,000 to 65,000 pounds, as specified for railway bridges.

TABLE II.—COMPARISON OF THE PHYSICAL AND CHEMICAL PROPERTIES SPECIFIED FOR OPEN-HEARTH PLATE AND RIVET STEEL.

	Association of American Steel Manufacturers, February 6, 1903.	Association of American Steel Manufacturers, October 23, 1896.	Amer. Soc. Test. Mat. Stand. Spec's, August 10, 1901.
PHYSICAL PROPERTIES.			
Extra Soft Steel:			
Ultimate strength	45,000 to 55,000.	45,000 to 55,000.	45,000 to 55,000.
Elastic limit . .	½ ultimate strength.	½ ultimate strength.	½ ultimate strength.
Elongation in 8″ .	28 %	28 %	28 %
Cold and quench bends	180° flat.	180° flat.	180° flat.
Fire-box Steel:			
Ultimate strength	52,000 to 62,000.	52,000 to 62,000.	52,000 to 62,000.
Elastic limit . .	½ ultimate strength.	½ ultimate strength.	½ ultimate strength.
Elongation in 8″ .	26 %	26 %	26 %
Cold and quench bends	180° flat.	180° flat.	180° flat; also a homogeneity test.
Flange or Boiler Steel:			
Ultimate strength	55,000 to 65,000.	52,000 to 62,000.	55,000 to 65,000.
Elastic limit . .	½ ultimate strength.	½ ultimate strength.	½ ultimate strength.
Elongation in 8″ .	25 %	25 %	25 %
Cold and quench bends	180° flat.	180° flat.	180° flat.
Boiler Rivet Steel . .	Use "Extra Soft Steel."	Use "Extra Soft Steel."	Use "Extra Soft Steel."
CHEMICAL PROPERTIES.			
Extra Soft Steel . .	Not over 0.04 % phosphorus. Not over 0.04 % sulphur.	Not over 0.04 % phosphorus. Not over 0.04 % sulphur.	Not over 0.04 % phosphorus. Not over 0.04 % sulphur; 0.30 to 0.50 % manganese.
Fire-box Steel . . .	Not over 0.04 % phosphorus. Not over 0.04 % sulphur.	Not over 0.04 % phosphorus. Not over 0.04 % sulphur.	If acid, not over 0.04 % phosphorus. If basic, not over 0.03 % phosphorus. Not over 0.04 % sulphur; 0.30 to 0.50 % manganese.
Flange or Boiler Steel	Not over 0.06 % phosphorus. Not over 0.04 % sulphur.	Not over 0.06 % phosphorus. Not over 0.04 % sulphur.	If acid, not over 0.06 % phosphorus. If basic, not over 0.04 % phosphorus. Not over 0.05 % sulphur; 0.30 to 0.60 % manganese.

THE REQUIREMENTS FOR STRUCTURAL STEEL FOR SHIP-BUILDING PURPOSES.

TOPICAL DISCUSSION.

E. PLATT STRATTON.—The character of material entering into all steel and iron ship construction in this as in other maritime countries is regulated by the Classification Societies of such countries, which are the organizations created for the supervision and certification of the character and structural condition of all merchant craft, under advisory committees, for the guidance of marine underwriters, ship-owners, bankers, and merchants, all of whom, either at the time of a vessel's construction or ultimately, become the real parties in interest not only in the ships themselves, but in their cargoes as well, the value of which often amounts in a single year to from fifty to seventy-five times the value of the ship or vessel transporting such cargoes; hence it is that the insurable values of such heterogeneous masses of valuable cargo always control directly or indirectly primarily the construction, and secondarily the classification of all merchant shipping in this and other countries. Mr. Stratton.

The rules of the American Bureau of Shipping, under whose Rules and Classification a very large majority of all American vessels are built and classed, require that all steel plates, angles, and shapes shall have a tensile strength of from 58,000 to 68,000 pounds per square inch of section and an elastic limit of one-half the ultimate tensile strength, and a reduction of area at the point of fracture of at least 40 per cent., and an elongation of 22 per cent. in 8 inches for plates 18 pounds thick and over, and 18 per cent. for plates under 18 pounds thick. Material of greater ultimate tensile strength than 68,000 pounds per square inch and not above 70,000 pounds per square inch may be accepted, provided the elongation and reduction are as specified and the bending tests meet the requirements. Shapes and angles in excess of 68,000 pounds tensile strength per square inch must also be capable of being efficiently welded. Bending specimens for all material

Mr. Stratton. must stand bending through 180 degrees on a radius of one-half its thickness without fracture on convex side, either cold or after being heated to cherry red, and quenching in water at 80° F.

In view of the foregoing requirements and years of experience therewith connected, I believe the facts fully justify the statement that a large majority of all the ship material manufactured in this country comes and will continue to come within the limit or standard of from 55,000 to 65,000 pounds, as adopted by the American Railway Engineering and Maintenance of Way Association. Ship plates ranging from 58,000 to 62,000 pounds insures a material sufficiently hard to meet the requirements under all of the conditions incident to its use in any portion of a ship's hull, not excepting the higher or greater stresses common to the shear, bilge, and garboard strakes, while 55,000 to 58,000 pounds material will insure a most satisfactory result in angles, bulbs, and shapes generally, and particularly where the conditions require heating and shaping of such material over the anvil or otherwise. With such facts before us it is safe to assume that there is no mechanical or architectural structure of modern times that appeals more strongly to us for a standard specification than material entering into the construction of hulls of all merchant vessels, whether of the sea-going, lake, bay, or river types.

As early as 1885 the chief classification society of Great Britain permitted a reduction of 20 per cent. in the scantlings entering into the construction of steel vessels from that adopted for vessels of iron, and they fixed the required tensile strength of steel at 28 to 32 tons, or 62,720 pounds, as a minimum and 71,680 pounds as a maximum, the elongation required being 16 per cent. in 8 inches, and these requirements are still maintained in England with the single exception that the required elongation has been increased to 20 per cent. in 8 inches. Eighteen years of experience there has probably established the fact that these requirements are the best that can be arrived at in a country where their ore is of a low grade and where any improvement in the product has to be reached by compounding with a better and more expensive quality of ore imported chiefly from Spain; hence it is fair to assume that a steel of 62,000 to about 72,000 pounds can be most

advantageously produced under the conditions that control locally in England, and without reference to the richer and more plentiful ores of America. Mr. Stratton.

H. G. GILLMOR.—The Bureau of Construction and Repair of the United States Navy Department, with which I am connected, is responsible for everything in connection with the hulls of vessels built for the United States Navy. It has, for a number of years, maintained a system of inspection, whereby an accurate record of the physical and chemical properties of each piece entering into the construction of every vessel built for the United States Navy is kept in such a form that at any time any piece can be located and the records as to its properties at the time that it was inspected ascertained. Mr. Gillmor.

In preparing the specifications for hull material, it was felt necessary to provide for at least three things:

1. The strength required in the ship's structure to meet the conditions met at sea.

2. The properties necessary in order to permit the material to be successfully manipulated during the construction of the vessel.

3. The properties desirable to limit the injuries caused by such casualties as grounding, etc., to which seagoing vessels are liable.

The first specifications drawn for shapes and plates required a tensile strength of about 60,000 pounds. This 60,000 pounds tensile strength requirement has been adhered to practically constantly for plates, and about the same requirement for shapes, with a preference in the case of shapes for going above rather than under 60,000 pounds.

The result of our experience with material of these requirements has shown that plates and shapes of about 60,000 pounds tensile strength are very satisfactory, all things being considered. In very few cases have failures occurred in working during construction, and in all such cases of failure the record of the material has been investigated and its physical and chemical properties ascertained, with the conclusion generally that the material failed through improper working or through accidental causes not attributable to the characteristics of the material. The conclusion is that adherence to the specifications at present in force will give a

Mr. Gillmor. material which will work properly during construction of the ship, giving a minimum of failures in working, and, at the same time, insure suitable strength on moderate scantlings in the finished ship. A uniform specification, permitting material from 55,000 to 65,000 pounds tensile strength, might be equally satisfactory for the purpose, but the experience of the Bureau of Construction and Repair has led them to specify a minimum of 57,000 pounds' tensile strength. What the effect of a further reduction in this minimum to that proposed by the Committee would have on the suitability of material for all purposes could be ascertained definitely only after the modified requirements had been in operation for a considerable time. In view of the eminently satisfactory results obtained under the present limits fixed by the specifications for such material, the Navy Department would probably be reluctant to make a change altering these limits until it could be shown conclusively that such alterations in the limits would have no attendant deleterious effect upon the quality of the material supplied.

The Bureau of Construction and Repair would probably differ considerably from the Committee upon the question of uniform specifications on rivet steel. We have at times in the past specified as much as 60,000 pounds per square inch tensile strength for rivet steel, but have never at any time allowed, under specifications for this material, less than 57,000 pounds tensile strength. With 60,000 pounds the rivets drove satisfactorily and the bottoms in which they were driven are now old and have given excellent satisfaction after much service and repeated dockings. We know, therefore, that we can go as high as 60,000 pounds' tensile strength and get a rivet which will at once drive readily and be entirely satisfactory in the ship, and we know, also, that rivet work gotten under the present specifications is entirely satisfactory. For the ship-builder, riveting is an item of the greatest importance, and while, therefore, rivets required by the Bureau of Construction and Repair are more expensive to manufacture than might be considered desirable in the case of other large consumers of rivets, where the conditions as to the greatest strength with the least weight do not exist as they do in the case of naval vessels, the Bureau of Construction and Repair probably could

not accept any considerable reduction in their requirements for this class of material. Mr. Gillmor.

JESSE J. SHUMAN.—In conversation with the American manager of the British Lloyds about their specifications, which call for about 62,000 to 71,000 pounds' tensile strength for plates and shapes, he made the argument that this higher-carbon steel will resist rust to a greater extent than does the softer steel used by the American shipyards. I should like to ask the gentleman who has just spoken for his opinion of that argument. Mr. Shuman.

MR. STRATTON.—This is not the first time I have heard questions raised in objection to American steel and theories advanced by British subjects for high-carbon steel, which seems to be largely a question of whose "ox is to be goaded" by the use of a softer, more ductile and more easily worked material than can be profitably produced in England, where the base of all iron and steel manufactured is either clay iron-stone or black-band ore, which is of the same character, except that it contains a quantity of bituminous matter, which gives it a dark color, from which it gets its name. Mr. Stratton.

In England the problem is how to produce a marketable steel from such a low or inferior grade of ore with the utilization of the largest amount of English ore and the smallest quantity of imported ore brought from other European countries. This was worked out by English ironmasters as early as 1885 in the form of a hard brash steel with a minimum tensile strength of 62,000 pounds and an elongation of 15 per cent. in eight inches.

As early as 1893 English material stamped "Clyde Silver Steel" was imported into this country and tested here for use in ship construction, it having passed Lloyds Classification Society's test at the mill in England. In the working of this material it was noted by the builder that it was remarkably severe on the punches, shears, and rolls, as compared with American material, and in a bending test of some ten samples of angles eight of them split in the throat while being gently flattened out on an anvil; and in working the first garboard plate a set of new rolls was broken, which was purely attributable to the hardness of the material. This was delivered in this country at a cost of 1.4 cents per pound; American steel at the same time was worth 1.6 cents. The builder,

Mr. Stratton. however, stated that in the light of his experience as to the bad effect this steel had produced on his tools, he believed that American steel would have been cheaper and more satisfactory at 2 cents per pound more.

The only change made in the rules and conditions governing British ship-building material since 1885, as far as my experience goes, is an increase of the elongation from 15 per cent. to 23 per cent. in eight inches, which is probably attained by a slight increase in the rolling of the material. Another objection to such high tensile steel is its liability to crack from the application of heat either in shaping or working.

If the ores of Britain were hematite, instead of argillacious, her ironmasters and classification societies would be looking for conditions germane to those of this country, in the form of a ductile steel, rather than a hard brash material, which is difficult to produce here, much harder to work, less satisfactory, and less enduring under all the conditions of use, abuse, and neglect.

Mr. Kinkea J. C. KINKEAD.—As regards rusting, I think it is acknowledged that iron is less liable to rust than steel; and that is noticed in some iron mills when they put steel in sections of bar iron. In a pile of material of this kind every bar containing steel can be distinguished on account of the rusting of the steel. Iron is a purer product than steel, and I have always considered that the harder the steel the more quickly it will rust.

Mr. Mathews. JOHN A. MATHEWS.—I have made a few observations in regard to corrosion. I had a series of steels, which included both plain carbon and alloy steels, including nickel, chromium, and molybdenum. Samples of these, in the form of machined test-pieces, were left exposed to atmospheric corrosion for some time. I then noticed that they became corroded, but that the degree of corrosion or rusting differed widely in different bars. I sorted them out in the order of the rusting, and was much surprised to find that in doing so I had arranged them exactly in the order of their carbon contents; the lowest carbon plain steel was least corroded. I could trace no connection between the atmospheric corrosion and the percentages of chromium, nickel, or molybdenum present. The steels ran from 0.04 per cent. carbon to 0.54 per cent. carbon. The total impurities, other than carbon

and the added metals above mentioned, never equalled 0.2 of 1 per cent. When I tried the influence of corrosion in acid the results were quite different, but by atmospheric action the steel containing only 0.04 per cent. carbon and total impurities below 0.20 per cent. was practically unrusted during the time over which my observations lasted—a period of several weeks. Mr. Mathews.

SPRINGS AND SPRING STEEL.

By William Metcalf.

In compliance with a request for a paper on the subject of "Springs," it may be well to begin with a short history of the conditions and changes that have occurred in the past thirty years in car and locomotive springs.

Thirty years ago, when the writer first became interested in springs, Bessemer and open-hearth steel were undeveloped infants and their uses were mostly experimental for everything except rails and plates. Bolster springs were made mostly of gum, gum and coils of steel around them and gum in boxes, in great variety; also of coiled springs of astonishing variety. There were helices and volutes, round, flat, square, beveled, oval, egg-shaped, and nondescript sections of bars, used for both bolster and drawbar springs, of steel made of either the old style German steel or of crucible steel. There were double, single, and half volutes, and helices in groups of single coils and others of different diameters one within the other. For elliptic springs we had flat, concave, ribbed, and corrugated bars.

These springs were covered by patents as numerous as the varieties, and, of course, each kind of spring was the best in the market. Specifications for springs were limited to space to be occupied and load to be carried; it was go-as-you-please for the manufacturer, scrambling and fun for the traveling men, and all around confusion worse confounded. The gradual introduction of open-hearth and Bessemer steels, sure winners because of their cheapness, promptly drove out the gum altogether, and more slowly but inevitably drove out the crucible steel. Crucible car-spring steel is still heard of occasionally from the few who have not advanced with the art.

The first effects of the introduction of these cheaper steels were failures innumerable, until careful railroad men were driven nearly wild. Before crucible steel was entirely driven out one maker was asked to make the lightest possible spring to go into a given space and carry a given load for the then common 30,000-

pound freight car. The result was thirty-two (32) pounds to a group, one hundred and twenty-eight (128) pounds to a car; they worked admirably, the springs were adopted and many thousands were ordered from different makers. A few months later the same maker was asked to make the heaviest spring he could put into the same space for the same load, because the light springs were breaking faster than they could be replaced. The result was a nest that weighed seventy-two (72) pounds, or two hundred and eighty-eight (288) pounds to a car, a gain of one hundred and sixty (160) pounds for the manufacturer. Shortly after, he was sent for again to consult about a proper specification, to which he replied that the proper specification was to specify his springs, and he was told promptly that the great railroads of the country could not, and would not, be tied to one concern; that although they were buying springs on a five-year guarantee the breakages were so great, even of the heavy springs, that to insist upon the guarantee would, they were sure, break up every one of the spring-makers, and that would be the worst break of all.

To take a back step and return to gum and crucible steel exclusively would be a confession of weakness in the mechanical department amounting to almost imbecility, and there seemed to be no relief except through a scientific study, careful experiment, and proper specifications. This was the beginning of specifications for springs, and probably the leader for many others.

The first specification of which the writer has any knowledge was for the steel, and was due to our worthy President. He wisely ignored the mode of manufacture, and devoted himself to getting the best material consistent with reasonable cost of manufacture, not demanding something impracticable, not expecting a dress suit at a shoddy price, and equally determined not to have shoddy when he paid for good wool. The writer, for one, kicked against the close limit on carbon, but all to no purpose. The result was the now famous and almost universally accepted P. R. R. specification for spring steel now known everywhere as the "Standard Specification Spring Steel," and it has proved to be entirely reasonable because it can be made for a reasonable price, and when it is well made it is entirely satisfactory.

Following this, there came from the mechanical department of the same railroad the first reasonable and sensible specification for coiled springs. A circular section, the round bar, was adopted for all coils, because the strain was torsional, and this round section gave the maximum resistance to torsion. Calculated from the best known formula for torsion a complete set of springs was designed for the various uses about a car. Upon the first trial the springs proved to be about 33 per cent. too strong; this led to a discussion between the spring-makers and the railroad engineers as to who was at fault. Naturally, each fellow insisted that he was right and the other fellow was wrong. The writer took the matter up by making some springs that were of the specified composition and the bars of the specified size as exactly as they could be rolled on a large scale, not going into a refinement of thousandths of an inch; then he saw that they were treated properly both in the coiling and in the hardening and tempering. They were certainly about 33 per cent. too strong. This led to a consideration of the formula; it seemed at first sight that if torsion were the only resistance the closing down of a coil must lead to a compression of the tempered steel that was simply impossible. Then where did the steel go in compressing the spring? Probably the ends slipped around the base, adding so much to the coils. A spring was placed in the testing machine between two clean smooth steel plates, and the position of the ends marked. Upon compressing the spring the ends did not move. Next the pressure was released, and by means of a small square set against the sides of the spring the diameter was marked on the base plate as well as the ends; then the spring was closed again and again the ends did not move. A trial with the square now showed that the spring had increased in diameter; at its middle height, one-fourth inch, it was barrel-shaped. The spring was six inches in diameter and eight inches high; this meant that the pressure had bulged a six-inch half-circle arch one-eighth inch at the crown, or it had apparently expanded a six-inch circle one-fourth inch in its diameter. This accounted for the increased strength above the formula requirement, and also when the writer considered the complication of strains involved in a combination of torsion and flexure produced by an end pressure, it drove from his mind any further

consideration of a formula. There may be mathematicians who could figure it out, but the writer is not one of them.

Assuming now that the springs are formed either by coiling the helices or arching the plates of elliptics, the next operation is the hardening and tempering. Although the differences in temperature necessary to produce the best hardening for different quantities of carbon are apparently slight, as shown by the heat color, they are very important, and are best acquired by the experienced eye possessed by a man of good judgment and not color-blind. The hardening and tempering of coiled springs is a comparatively simple matter if the temperer knows the carbon with which he is dealing. The objection to the carbon limits mentioned before was that we had been accustomed to making springs of every carbon from 0.60 to 1.30, and the limiting of carbon to 0.90 to 1.10 threw out of use a large amount of steel. Now that specifications have been changed so that coiled springs may be of any carbon from 0.70 to the highest, that objection has been removed, and the results will be just as good if the best conditions are observed.

The lower carbons should be put into the larger bars, because the largest bars are the most difficult to harden safely, and the difficulty increases in a geometrical ratio with the increase in carbon. A good rule is to put the 0.70 to 0.90 carbon into bars of more than one inch diameter; bars from an inch to three-quarters of an inch, 0.90 to 1.10 carbon; bars from three-quarters to half an inch, 1.10 to 1.20 or even 1.30 carbon, and little rods below half-inch into any high carbon up to as much as 1.45. This was the old practice with crucible steel, and the spring-makers were always informed of the carbon they had to deal with; the result was that breakages in the shop or failures in service were very rare. Steel of 0.60 to 0.90 carbon was hardened in water; sometimes, with about 0.90 carbon, a film of oil was used on the water. From 0.90 to 1.10 carbon about four or five inches of oil were used on the water, and for higher steel, oil was used and kept cool by an external tank of cold circulating water, or by a coil of pipe inside of the tank with cold water running through.

Coiled springs require so little manipulation after coiling that they are usually at a proper heat for hardening as they leave the

machine; care should be taken, however, in heating for coiling; they should be of an even temperature throughout the bar, and neither too hot nor too cold. If they are too hot the grain will be coarse and fiery, and even if they do not happen to break in testing they will be brittle and liable to break in service. If too cold they will not harden thoroughly, and if they do not set in testing they will probably set in service. As to the heat, it needs to be slightly higher for mild steel than for high carbon; in general it should be just a slight shade above the recalescent point, but that is a matter not readily grasped by the average worker, and a good practice is to aim for a nice, medium orange color for high steel, and a little brighter orange for the milder steels. Good sense and experience and honest attention to the work are the best guides.

Tempering must be suited to the carbons: 0.70 to 0.80 carbon will require very little drawing; 0.90 to 1.10 may require the oil on them to flash, and for higher carbons the oil may be burned off; above 1.30 carbon a heat that barely begins to show color will generally give a good spring temper. In tempering, as in hardening, good sense and good judgment are the best guides.

Helical extension springs require more care and exact treatment than compression springs; whether it be that they are liable to be pulled out so as to be strained beyond the elastic limit, or that the uncoiling is in a continued direction of some strains set up in coiling, and so causing more injurious strains, the writer cannot say, but a large experience has demonstrated clearly that extension springs as compared to compression springs are much the more troublesome, so that great care must be used to produce satisfactory results.

ELLIPTIC SPRINGS.

In dealing with elliptic springs the problem is somewhat different from that of coiled springs. There are many more pieces to deal with, and each one must be shaped, hardened, and tempered separately, and then all assembled and brought to a neat fit. The heating for shaping and hardening and tempering should be done carefully, and in general the same as has been described for coiled springs.

It seems to be the fact that there is comparatively little trouble with double elliptics, because, probably, when they are closed down solid they have a bearing upon their two parts, just as a coiled compression spring has, and therefore they are not liable to be strained beyond the elastic limit unless they receive a blow that is powerful enough to crush and break the material.

The case of the semielliptic, where the spring rests on the middle with the ends turned up to receive the load, as in a locomotive, is very different, and is comparable to the case of the coiled extension spring; there is no final bearing for the ends, and by a sudden jar causing an excessive motion they may be strained away beyond the elastic limit and broken. It is understood that these springs now give more trouble than any others and that to get them satisfactory is a serious problem.

The standard specification for locomotive spring steel retains the original low limits for phosphorus, sulphur, silicon, and manganese, and carbon between 0.90 and 1.10; this is well, first, to insure good material as far as it is possible to get it, and second, because all of the bars are flat, of nearly the same section, and there is no reason for allowing a wider range in carbon; steel can be had within these limits without any increase of cost, and now that coiled springs may be of any carbon from 0.70 to the highest, all off heats can be used for helicals without any loss to the steelmaker.

It is a common practice to form the plates in a mould, take them out, and adjust them to a templet; twist them a little here, pound them with a hammer there, hold another spot with cold tongs, and finally, when the piece is shaped to the taste of the operator and is of many different colors of heat, and strained here and there by hammer blows, to plunge them into the oil bath to harden them. This is certainly all wrong; it is a quick, cheap way to get out a big product, and it is sure that every plate so treated is dosed with injurious strains that may result in a mysterious and unaccountable fracture. Plates so manipulated should be put in a proper furnace and brought to a uniform, correct heat, before quenching; this heating would remove the uneven strains and make a much better plate. This would require a little care, a little time, and possibly a small increase in cost; the

question is, would it pay if it increased the life of the spring, reduced the number of breaks, and kept the engines longer on the road?

Another point needs attention when hardening in oil, both for helices and elliptics; the oil should be watched, a little fresh oil should be added every day, and finally, when the whole mass has become pretty well burned, so that it appears as if it were mixed with sand, it should be thrown out, the tank cleaned, and filled with fresh oil. Worn-out oil loses its power of convection largely, and will not harden the pieces as they should be; if it is attempted to correct this by having the springs a little hotter, then the grain will be raised and the result will be fiery, brittle plates and more mysterious breaks.

Compared to a fine tool, a razor, or any similar article, a locomotive spring is a comparatively coarse article, but nature did not make one set of laws for steel for milling cutters, taps, reamers, etc., and another set for steel for locomotive springs; the laws are all the same, the strains are the same, the sensitiveness is the same. The average spring steel contains more impurities, phosphorus, sulphur, etc., than fine tool steel, and just for that reason it is not only not so strong in the tempered condition as the finer steel, but it is also far more sensitive to uneven strains and will break under conditions that a piece of finer steel would endure safely. In the absence of laboratory tests and exact data on these points, it may be well to illustrate them by the action of clock springs and watch springs, which are fine enough to answer the purpose of laboratory work. These springs are spirals, and when well made are really wonderful in their work; probably everyone here has a watch which runs year in and year out with great regularity, and the running is done by a little spring that drives machinery of many times its own weight, often with a variation in speed of only a few seconds a month. A watch mainspring, about 0.002 or 0.003 of an inch thick, less than an eighth-inch wide, and several feet long, should be made of steel of 1.30 to 1.40 carbon.

The first attempt to make this steel in the United States led to trouble, of course; the steel was not uniform in quality, and was not properly melted, because it showed all sorts of temper in the same spring. It developed some other tempers also.

The requirement of the spring-maker was that the spring must be a perfect spiral; when pulled out straight and allowed to snap back it must coil into a spiral of even space between the coils through its whole length; also it must, when tempered, be of a perfectly even beautiful blue color. Such springs were submitted to the steel-makers, and they certainly were admirable works of art.

The American springs were any shape as far as even coiling went; they touched at one spot, were too far apart at another, etc.; were any color from a dark dingy blue to a brown; therefore, the steel was not of uniform quality, and so badly melted that the carbon was not evenly distributed. There was no room for argument; the springs told their own story. The steel-makers knew that the steel was uniform in quality and in carbon, that it was thoroughly well melted, and that the carbon was as evenly distributed as it was possible to have it in any steel. It was now their business to find the cause of the trouble.

After two or three years of struggling with the problem the cause was found in the annealing. The steel was cold rolled in long strips about three inches wide and one hundred to two hundred feet long. To get it down to 0.003 of an inch thick it had to be annealed, pickled, washed in lime water, and baked about six or eight times, and it can be readily seen that this required great care, skill, and close attention. The annealing was done in boxes, packed with coils of steel, filled in with fine charcoal, and the cover was luted on carefully. In spite of all care the troubles recurred, some coils made beautiful springs and others were worthless. Finally, a wise and expert worker of fine wire, Mr. Edwin Kidd, now of the Globe Wire Company, asserted positively that that steel never could be made right by annealing in closed boxes; it must be annealed in an open furnace so arranged that no flame could strike the steel directly, and yet not in a muffle. Then the operator could notice each coil, turn it, and watch it until it was heated just right, and then remove it from the furnace and place it in a warm, dry place to cool slowly. It was thought that his plan was impracticable, but the case was desperate, and the plan was tried with most remarkable results; it was a brilliant success, and that steel soon became famous for its excellence.

What is the explanation? It is very simple when you know, but it was a hard road to travel to the knowledge. In annealing in boxes the steel could not be seen and the heat could not be known; then the charcoal would become incandescent and run the heat too high, and the coil would be much hotter on one side than on the other; that meant that part of the coil would be of one grain and part of another grain, and greatly different structure. This difference in structure would remain in the steel until the spring was finished, ready for hardening and tempering; the heating would require but a few moments, and when heated the spring would have to be quenched immediately, because its small size admitted of no time for manipulation. Now, although the structure of steel changes rapidly in answer to any change of temperature, yet it does require a little time, and in this case that little time could not be allowed, the grain of the spring could not be evened up, and the result was an uneven spiral, varying color, and a bad spring all round, until the steel was annealed to an even grain and structure.

Consider this now as a long-continued, worrying, and costly laboratory experiment; and apply the facts to your car and locomotive springs; you are dealing with the same material, it has the same properties, the same forces are at work, and the same results will be had in greater or less degree. Possibly if you consider it seriously, you will conclude that it will be worth while for you to be careful in the manipulation of the springs which you wish to have to carry your engines and cars in safety.

TESTING.

Testing of springs is probably well understood, and need not be enlarged upon to any great length.

All springs are made higher than the finished height, to allow for the initial set which occurs when they are first closed down; this is necessary, because, if the temper were left so high that they would not set, they would nearly all break either in the test or in a very short time in service.

It is important in testing that springs be held down solid for a few minutes to allow for lag; a spring may be in a state of

unstable equilibrium and endure a quick closing and release without setting too low if soft, or breaking if too hard, and then soon fail in service; this condition can be detected by holding it down solid for a few minutes, giving the necessary time for the strains to develop.

The United States Government required springs for mortar carriages to be held down solid for sixty hours; this is just as unreasonable as not to hold them down at all; it is not on record that any spring broke after the first five minutes; but the holding them down for a few minutes under heavy pressure is important.

CHEMISTRY.

While it is not well as a general rule to specify a given chemical composition and a physical test, unless the engineer is a very expert steel-maker, it certainly was wise to fix a reasonable maximum of allowable phosphorus, sulphur, silicon, and manganese, and a reasonable range of carbon; the effect of these elements is well known, and excess can be guarded against, as it has been in the standards now adopted by all careful railroads, without any excessive cost or trouble to the manufacturers. It is assumed, of course, and properly, that if the chemistry is correct, the physical condition good, and the sizes are accurate, that the steel-maker's responsibility ceases, and as a general thing the rule works well, but it has its exceptions. Not long ago a prominent spring-maker received several carloads of steel which was well within the chemical limits, was sound, and rolled accurately; upon attempting to work it into springs the blanks nearly all broke in the process of forming; the steel was excessively red-short, and it was returned to the maker.

The cause of this was back of the engineer, and the chemist, at a point probably impossible to reach by specification, except to claim the right to test for red-shortness, and this should be done. There can be little doubt that this trouble was due to excess of oxygen, an element that cannot well be determined by ordinary analysis. That an excess of oxygen will produce excessive red-shortness is beyond dispute.

After many years of analyzing and experimenting by Professor John W. Langley, supplemented by many tests in the shop, to locate if possible the cause of the difference in strength in the tempered condition, between Bessemer, open-hearth, and crucible steels of practically even composition, the conclusion was reached that the cause was to be found in the difference in the quantities of oxygen, nitrogen, and hydrogen found in the steels; in Bessemer steel great quantities of these elements are blown through the mass; in open-hearth great quantities flow over the surface of the steel for hours, and much is absorbed; in the crucible only the amount that is in the pot or that may pass through the sides can get into the steel.

That these elements make a great difference is easily observed when a crucible happens to become uncovered during the melting, as sometimes occurs; if a hundred ingots be topped and set up for inspection and only one has been exposed to flame by the crucible becoming uncovered, the inspector will notice it immediately, mark it "gas," and relegate it to the scrap heap.

There is no good reason apparent why an atom of oxygen, nitrogen, or hydrogen may not be as potent as an atom of phosphorus, sulphur, or silicon, and they are all present in greater or less quantity. Professor Langley's conclusion was that oxygen is the head devil; the writer held to nitrogen for a long time as his pet mischief-maker, but it seems probable that Langley is more nearly correct.

These remarks are not meant to belittle bessemer or open-hearth steel in any way; their great merits and usefulness are too well established to leave them open to criticism. The trouble is not in the method, it is in the man. Given the best material that the world can produce, and it will not make good crucible steel if it is not melted properly, and no subsequent treatment will make a badly melted ingot a piece of good steel. It is the same with bessemer and open-hearth, bad blowing or bad melting cannot be cured by good chemistry.

The red-short steel referred to doubtless came from a wild heat; the melter knew it, the roller knew it, and probably the superintendent knew it; they were all working for product, and they knew how to work that steel into pretty bars, but the spring-

maker did not know how to work it into springs, and it is probably well for his employers that he did not know.

We have now covered the ground that belongs properly to the engineer, the spring-maker, and the inspector, and have tried to show how the work should be done, how to detect errors, and how to correct them. This brings us back to the steel-maker and out of the domain of the steel users; all steel is made good or bad in the crucible, the open-hearth furnace, or the Bessemer converter; if the steel is good there can be no excuse for bad springs, and if the steel is not made good by good melting or blowing, it cannot be made good by any subsequent treatment. This matter rests then with the steel-maker, because it will not do for the engineers or inspectors to attempt to regulate shop practice unless they are ready to assume all of the consequences.

During the latter part of the Civil War the Government sent construction officers to the gun foundries; these gentlemen were to see that the right kind of iron was used, and to see the guns cast. They did see that iron of the recognized standard brands was put into the furnaces, and it is needless to say that they did not know anything about its quality. They also saw guns cast; this occurred after noon, and sometimes when the furnaces were slow they got in a hurry to go away, and would say it was time to cast the guns; the answer always was, "All right, give us a written order to cast the gun, you agreeing to accept the result, and we will cast at any time you wish." The reply followed, "No, you must submit the gun to all regular tests of course." And the argument ended, "Very well, if we are responsible, we will use our own judgment until the gun is submitted for inspection." The same rule must apply to any manufacturer; if he is to be held responsible he must not be interfered with in his management.

A good melter, of sound judgment and correct eye, knows exactly what he is doing and precisely what he will get; there is no pyrometer or spectroscope that is equal to a well-trained eye to inform one what is going on, and it is doubtful if any machine will ever be invented that will be as useful as a good eye. All that the steel user can do is to plead for good work, and be willing to pay a fair price for it; the rush and drive in the mills, the

keen, fierce competition of different manufacturers and lively salesmen, and the desire of the purchasing agent to keep down costs are potent factors for poor work. The engineer wants the best he can get for his purpose, and he often finds that these factors have placed him between the devil and the deep sea.

It is hoped that what has been said will lead properly to the conclusion that nothing has been suggested that will cost anybody one cent; it is meant only as a plea for honest effort, reasonable care, and close attention to every detail. These will result in general satisfaction, and any other course will lead to disaster.

THE ROLLING OF PIPED RAILS.

Topical Discussion.

By Albert Sauveur and Robert Job.

Albert Sauveur.—I should like to preface my remarks by the expression of my belief that I am perfectly impartial in the matter of piped rails. I am not a consumer of rails, nor am I a manufacturer of rails. I am interested in this matter purely from a professional standpoint. It is well known that all rail steel ingots pipe and that this defect covers from 20 to 40 per cent. of their lengths. It is evident, therefore, that to convert into rails sound metal only, we would have to discard all the way from 20 to 40 per cent. from the top of each ingot; that would be the only safe way. However, as a matter of fact, few, if any, rail mills discard over 10 per cent. Such being the case, from 20 to 30 per cent. of piped metal remains in the ingot. What becomes of this metal? We evidently convert it into piped rails. I do not hesitate to make the statement that in our present practice the first rail rolled from an ingot is, in the majority of cases, a piped rail; it is a defective rail, and therefore more liable to fail; at any rate, it is a rail which is not as good as the other rails. I think this is a very serious matter. It is a surprise to me that this question has not been faced more frankly before. To me, the refinements which are introduced into the specifications for steel rails regarding their chemical composition, their physical testing, shrinkage, etc., appear farcical, when we ignore a fact of this character—when we ignore the fact that we are producing one defective rail out of every five or six rails rolled. I am not stating anything that is new; you all know that such is the case. I merely want to bring the matter to the attention of the Society, to see if there is anything to be done to prevent the rolling of these piped rails. Shall we prescribe that the manufacturer shall cut off enough to get rid of the pipe? Shall we test every first rail rolled from an ingot to see if it is piped? Shall we test, for instance, the crop end of every first rail, and if that crop end shows piping, Mr. Sauveur.

Mr. Sauveur. reject the first rail? The presence of piped metal can readily be detected. If a piped rail be properly polished and etched, the pipe metal which cannot be welded perfectly will be eaten away by the acid and the location of the pipe will be revealed very plainly. I have been called upon to investigate the cause of failures of a great many rails, and in most cases I was able to trace it to the presence of a pipe in the rail. If such tests are unreasonable or impracticable, we should surely prescribe in a most positive manner that the drop test shall always be made on the first rail of the ingot and never allow it to be made on any other but the first rail. It is a very defective procedure to test that member of a series which is likely to be the strongest, in order to throw light upon the quality of the whole series. It is the weakest member which should be tested.

My desire is merely to call this matter to your attention. It seems to me that manufacturers should not go on making piped rails and consumers should not go on buying them. I think there is in this consideration more than a mere question of commercial expediency. We should reflect upon the loss of life which has been caused in the past through the breaking of piped rails; the loss of life which will be caused in the future by the breaking of such rails if we continue in our present course.

Mr. Job. ROBERT JOB.—The general appearance of a piped rail is unfortunately very familiar to everyone who has to do with the fractures of rails in service. I have brought photographs of a couple of examples which recently came under my observation. In this case (Fig. 1) I polished off the transverse section of the rail and then etched it lightly with iodine. I find that this method of etching gives a very clean, bright appearance, and shows the form of the pipes very clearly. Another rail which broke in service a short time ago shows a pipe running from almost the very top of the rail down through the head and web almost to the bottom of the rail, and extending up through the entire length. The section which I had was perhaps 4 feet long, and it was possible to look clear through that piece from end to end and read writing beyond.

As to the number of fractures which result in track due solely to piping, we have found relatively few when we consider the total

number of rails which are put in the track, but in following up this matter I have been interested to note that taking all of the fractures which have occurred during several years, perhaps 75 per cent. of such rails have had pipes extending through them to a considerable extent. In many of these cases, of course, the pipes were merely contributing agencies—that is to say, they were not present in sufficient extent to cause in themselves an actual fracture, although they added to the weakness from other sources and ultimately produced fracture. Mr. Job.

How to eliminate the pipes from the rails is, of course, the vital question. Professor Sauveur has mentioned—and he is certainly correct—the advantage of taking the test rail from the rail from the top of the ingot. It seems to me that that is the only rail we ought to take for the test. I may say further that our practice is to take one test from the top of an ingot from each heat. At the outset there was more or less discussion in regard to the matter, on the ground that such action might cause delay at the mill. I can state, however, that such has not been the case, and throughout our practice we have not had the slightest difficulty from holding the mill or causing any delay where the quality was normal. We find also that we have in the drop test an important ally in the detection of piped rails. We find,

Mr Job. for instance, with a 23-foot drop of 2000 pounds upon rail butts 3 feet between centers, that a large majority of the rails which are broken contain pipes. It seems to me that is pretty clear evidence that a fairly severe drop test is an excellent detector of pipes. It does not always detect them, but it frequently does, and it is certainly an aid. Thus I think that by combining our drop test as we have it at present with the test of the rail from the top of the ingot, the consumer has at least a fair chance of detecting any seriously piped rail.

GENERAL DISCUSSION.

M. H. WICKHORST: It is fortunate for us that rails do not fail oftener than they do. Only a short time ago we had a case of a rail breaking and causing a wreck in Iowa, and while there was no loss of human life, there was an incidental loss of about $10,000 to the railroad company. The investigation of the failure showed that it was due to a piped rail. In this instance the web was so weak that a portion of the head, a foot or two in length, subsided, and when that occurred the rest of the rail broke and quickly caused the wreck. I submit a photograph showing etched sections of two rails, one of the broken rail and one of a good rail next to the broken one. I also submit a drawing showing the nature of the fractures. (See page 126.) Mr. Wickhorst.

JOHN MCLEOD: I feel there is a burden laid on the shoulders not only of the manufacturer, but also on the representative of the consumer who goes to the works of the steel manufacturer and attempts to criticise his product. I believe that I could go to the Edgar Thomson Steel Works and inspect rails with the moral certainty that I had accepted rails which were practically free from piping. I think a great many of those present are familiar with these works; they know where the ingot is placed in the so-called soaking pits; how long it is kept there; that it is Mr. McLeod.

N.

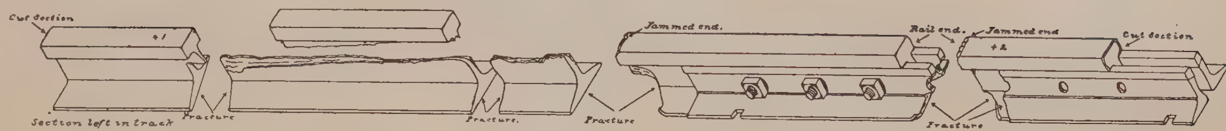
W. —— E.

S.

BURLINGTON ROUTE LABORATORY, AURORA, ILL.

Broken Rail from Wreck at New London, Ia.

Occurred March 31, 1903.



Chemical Analysis.

	Carbon.		Phosphorus.		Sulphur.		Manganese.		Silicon.	
	1.	2.	1.	2.	1.	2.	1.	2.	1.	2.
Head	0.61	0.61	0.071	0.090	0.032	0.034	1.03	0.99	0.062	0.065
Web	0.58	0.54	0.061	0.087	0.040	0.043	1.01	1.03	0.061	0.070
South flange	0.59	0.58	0.056	0.068	0.044	0.053	1.01	1.04	0.062	0.068
North flange	0.63	0.58	0.091	0.082	0.041	0.050	1.00	1.02	0.064	0.067

Borings taken from places marked 1 and 2.

then taken out and put through the blooming-mill and cut off in proper lengths, then recharged into the reheating furnaces, and so the process goes on. It would seem to me if I were going to criticise the material going into the rails, with a view to preventing rails that contain piping going into service, I would station myself at the blooming-mill where this cutting is going on, and I believe I could eliminate almost all the trouble by observing the condition of the end of the bloom after it has been sheared. If enough has not been taken off, take off a little more, and so on. I know that I personally have been decorated with all kinds of criticisms because I have always contended that the proper place for the inspection of any material is in the mill at the time of rolling. There is no better safeguard for a railroad company to take than to instruct the inspectors to go to the mills and to remain there during the process of rolling, whether by night or day. If the inspector will do that, I think that you will probably not get as many piped rails as you are possibly getting now. That you do get such rails is perhaps the manufacturer's fault; but I think the representatives of the railroad company should share any blame with us, because I am sure not one of our superintendents would think of shipping a rail he knows to be piped. But the superintendent cannot always be in the mills, and I think you are falling short in your duty in not having your representatives present in the mills when the operation of rail-making is being conducted for you. If your inspectors were present at that time they could cut out almost all of the piped rails, and the small percentage remaining would give you little or no trouble. Mr. McLeod.

MR. SAUVEUR: I had especially in mind the failure of our committee to stipulate in the most positive and clear manner that the first rail from the ingot should be the one tested. I have not yet seen any specification that puts that down in black and white, and I think it surely should be so put down. Mr. Sauveur.

MR. MCLEOD: While I consider this suggestion perfectly just, yet I think it also fair that if such tests be specified the requirements should be tempered. The specifications existing to-day are not based on tests of rails from the top of the ingot. You will admit that tests give after all only relative values. If the top rail of an ingot is to be tested, conditions should be imposed sufficient to prove that the rail will be satisfactory for the service to which it will be subjected. Since the other rails from the Mr. McLeod.

Mr. McLeod ingot will be better than the one tested, you should be as lenient as you can in framing the conditions of that test. I think it only fair to make that statement, and if the subject were approached in that spirit I think no manufacturer would object to a test from any part of the ingot.

The President. THE PRESIDENT: In other words, do not prescribe the crucial and extreme test for good steel for the piece that is possibly not quite so solid.

Mr. McLeod. MR. MCLEOD: That is the idea exactly.

Mr. Sauveur. MR. SAUVEUR: It seems to me that if we are going to test the first rail as it should be done, the test should be severe enough to produce failure if it be a piped rail; if not, the testing of the first rail would do little good.

Mr. Mathews. JOHN A. MATHEWS: I think it a very good idea to test the first rail and find out if it is piped; but it does not seem to me that the failure of that first rail in the test would be sufficient reason for rejecting other rails from that same ingot. It is, of course, proper to discover and reject the piped portion, but certainly the piped portion may fail though all the rest be good.

Mr. McLeod. MR. MCLEOD: I find myself obliged to take issue with Mr. Sauveur again. There are rails which after outliving their usefulness, on removal from the track are found to be piped to a more or less pronounced degree. It seems to me that every material should be criticised from the viewpoint of its intended use. The test for a rail should be sufficient to determine whether it is fit for the service intended. If a rail with a slight pipe in it will meet a test which has been intelligently conceived, then I think that rail is quite good enough to be used. You should take up the question of degree, because you know that in making a melt of steel the conditions are sometimes ideal and sometimes not ideal, but quite good enough. I think that should be taken into consideration when imposing conditions of tests for rails.

Mr. Sauveur. MR. SAUVEUR: As I understand it, it is argued that a piped rail is not necessarily a defective rail and might be accepted. Against this, however, I have my own experience, which shows that a large proportion of rail failures which I have had to investigate was due to the presence of piped metal, and Mr. Job has just told you that this has also been his experience: that at least 75 per cent. of the cases which he had to examine he could trace to the presence of a pipe.

THE CASTING OF PIPELESS INGOTS BY THE SAUVEUR OVERFLOW METHOD.

By Albert Sauveur and Jasper Whiting.

Introductory.—The formation of a cavity technically called a "pipe" in the upper part of steel ingots, under the ordinary method of casting, is too well known an occurrence to call for any description. If a "piped" ingot be cut in two longitudinally this defect will appear as shown in Fig. 1.*

Fig. 1.

The great advantage which would result from being able to cast pipeless ingots is, of course, appreciated both by producers and consumers—witness the strenuous attempts which have been made to eliminate this defect. In medium-high and in high-carbon steel the pipe occupies from 20 to 40 per cent. of the length of the ingot. In the manufacture of armor plates and of some expensive forgings as much as 40 per cent. of the ingot is discarded and in this way only metal free from pipe is converted into finished product. In the manufacture of other implements, however, it is safe to affirm that a sufficient amount of metal to insure absolute freedom from pipe is very seldom rejected. Hence the danger of turning out defective material. It is our opinion that a very large proportion of the failures of steel implements of all kinds in the process of manufacture, in the testing room or when in use, is due to the presence within them of this defect. The production of pipeless ingots, therefore, would not only do away with the rejection of a large amount of metal, a most important item, but it would also greatly reduce the production of defective implements. The commercial value of this

* From a paper on "The Development of Tool Steel." By E. L. French, American Association for the Advancement of Science, 1902.

last consideration will, we believe, be readily granted. From the knowledge that they are not placing on the market finished implements containing this hidden flaw—a cause of much weakness and of probable eventual failure—the manufacturers should derive a feeling of security which they alone can fully appreciate.

In the production of many implements where the cost of the work required is many times greater than the cost of the metal, as for instance in the manufacture of saws and many other tools, the handling of pipeless ingots would result in a saving considerably greater than would at first appear, because the presence of a pipe is in many cases only discovered when the implement is nearly ready for the shipping room, that is, after a large amount of expensive labor has been put upon it, and the cost of this labor is a clear loss to the manufacturer. Producers of such implements will, we believe, readily appreciate the importance of this consideration.

The Overflow Method.—In the method now to be briefly described, it is believed that a practical means has been found for the casting of pipeless ingots.

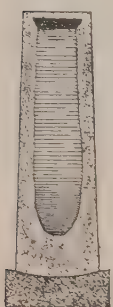


FIG. 2.

It will be sufficient for the purpose of this paper to recall in a few words the cause which induces the formation of the pipe.

After molten steel has been cast into an iron mold, the metal in contact with the bottom and the sides begins first to solidify. After a relatively short while the top of the ingot, which is exposed to the cooling action of the air, also becomes solid and the ingot now consists in a rigid metallic shell holding a mass of molten steel, as shown in Fig. 2.* As the cooling proceeds this solid shell increases in thickness, but since steel, like most substances, undergoes a considerable contraction in passing from the liquid to the solid state, the mass of metal which when liquid was sufficient to fill the space within the solid shell, will, after it has in turn solidified, be unable to fill it and a cavity must necessarily be formed in the upper part of the ingot. It is evident, therefore, that the formation of the pipe is due to the fact that

* "Iron, Steel and Other Alloys." H. M. Howe.

the top of the ingot solidifies while a considerable amount of metal below it is still liquid. Once the top has become rigid the contraction of the liquid interior in passing to the solid condition must necessarily result in the formation of a cavity or pipe. By retarding the solidification of the top we should, therefore, decrease the size of the pipe and if it were possible, in a practical way, to maintain the top liquid to the very last, that is, until all metal below it has solidified, the formation of the pipe should be altogether prevented. Efforts have been made in this direction, such for instance as covering the top of the ingot immediately after casting with fuel or with molten slag, or in preheating the top of the mold. All such attempts, however, resulted only in a slight decrease in the dimension of the pipe and were accompanied by practical objections which more than offset the small gain effected.

The aim of the present method is to maintain the top of each ingot liquid until all metal below has solidified and to do so without in any way interfering with the conduct of the mill operations or adding to their cost.

The method consists in so connecting a number of molds that the molten metal can overflow from one mold into the next, while pouring is continued in the same mold until any desired number of molds beyond have been filled.

In Fig. 3 is shown a diagram representing in elevation a number of molds which we shall suppose so connected that after one mold has been filled, if the supply of metal be continued into it, the excess of metal will overflow into the next which will in turn be filled. To take a particular case, let us suppose that we cast the steel into mold No. 1 and that after it has been filled we continue pouring into this same mold until we have cast into it sufficient metal to fill the next five molds. After mold No. 1 has been filled, the metal will overflow into mold No. 2, and when this one has been filled it will overflow into mold No. 3, and so on until six molds have been filled. It will be seen that by this method we maintain a flow of molten metal running over the tops of the solidifying ingots, and therefore retard the solidification of the tops, which is our desideratum. This should result in a reduction of the pipe, and, if sufficient molten metal be passed

over the tops, in the complete obliteration of this defect. The molten metal flowing over the tops of the ingots acts after the fashion of a sinking head, feeding the pipe, and therefore preventing its formation.

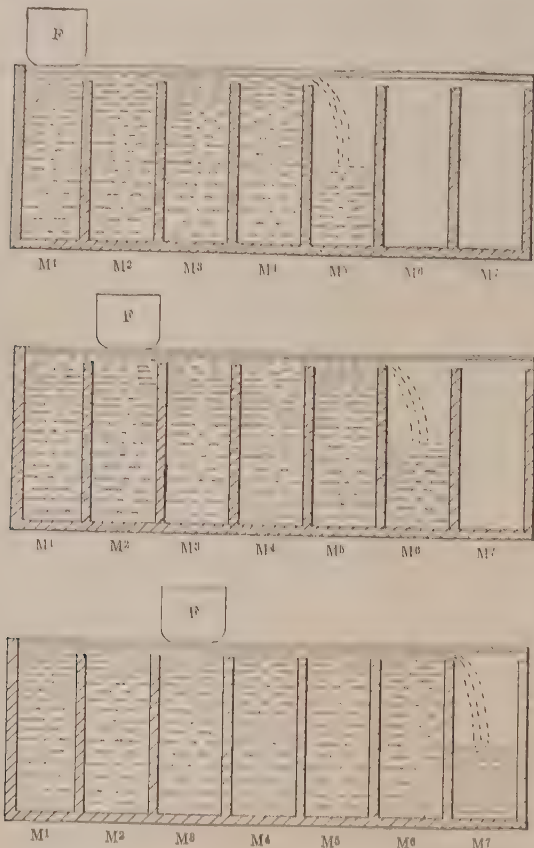


FIG. 3.

It will be seen that in the example we are considering ingot No. 1 will have enough metal cast upon it to fill five molds, ingot No. 2 enough to fill four molds, ingot No. 3 enough to fill three molds, and so on to the last ingot, which had no extra metal

passed over its top. The amount of molten steel flowing over the tops of these ingots decreases, therefore, as we pass from the first to the last ingot, and it should be expected that the effectiveness of the method in eliminating the pipe should also be greatest in the case of ingot No. 1 and should then gradually diminish.

Segregation.—It is well known that the segregation of impure metal in the upper part of steel ingots—that is, in the piped portion—is due to the fact that the impurities present in the metal, especially the phosphides, sulphides, and carbides, are more fusible than the metal itself, and have therefore a tendency to collect in the portion of the ingot remaining molten longest. In the overflow method these impurities should naturally rise to the very top of the ingot and should then be carried away by the flow of molten metal to be discharged into the next empty

FIG. 4

mold. Here, however, they should be diluted so largely by the metal from the crucible or ladle as to have but a very slight effect upon the average composition of the ingot. We have not as yet had the opportunity of testing the effect of the method upon the segregation of impurities, but from these theoretical considerations it should naturally be anticipated that if it does not prevent it altogether it should greatly diminish it.

The Overflow Method and the Casting of Crucible-steel Ingots.—Numerous experiments were conducted with crucible steel ingots in order to ascertain the practical value of the overflow method. The results obtained in casting six ingots, after the manner just described, are shown in Fig. 4, which is the reproduction of a photograph of the broken tops of these ingots. These ingots measured 3¾ x 5¾ x 20¾ inches and weighed 100 pounds. The

steel cast contained from 0.9 to 1 per cent. carbon and was produced in a regenerative crucible furnace.

Ingots of this size and grade cast in the usual manner had a pipe extending on an average about 8 inches downward. Turning our attention to the ingots cast by the overflow method, it is seen that No. 1 and No. 2 ingots are absolutely free from pipe. They are solid masses of metal to the very top. The metal which was cast upon these ingots had caused their top to remain liquid until the metal below it had become solidified, preventing thereby the formation of a pipe. No. 3 and No. 4 ingots show a small cavity measuring about 1 inch, while No. 5 ingot has a 4 inch pipe. No. 6, which is not shown here, was not, of course, materially improved. These experiments were repeated a number of times and the results obtained were in every case very similar.

The results which had been anticipated from purely theoretical considerations are, therefore, fully confirmed. From the appearance of No. 5 ingot we infer that the passing over the top

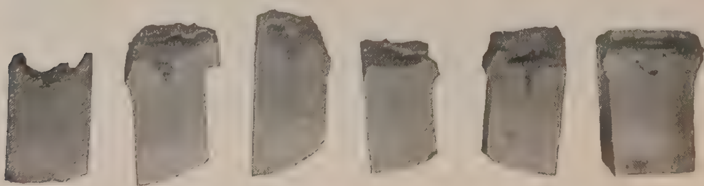


FIG. 5.

of an ingot of sufficient metal to fill one more mold by causing it to overflow into it will reduce the length of the pipe some 50 per cent., while the passage over the molten top of an ingot of enough metal to fill four more molds will result in the complete elimination of that cavity.

In Fig. 5 are shown a number of pipeless or nearly pipeless ingots obtained by the overflow method.

In casting six ingots then in the manner just described, while the first two ingots will be pipeless, the remaining ingots will have small pipes of increasing length. It may be readily conceived, however, that the overflow method may be conducted in a more continuous manner, so that enough metal will flow

over the tops of all ingots to make them pipeless, namely, in the present case, enough metal to fill four or five additional molds. If for instance, returning to Fig. 3, after having filled six molds by pouring in No. 1, the pouring be shifted to No. 2 and enough metal be cast to fill mold No. 7, and then the pouring be shifted to mold No. 3 and enough metal cast to fill No. 8 and so on, it is evident that the necessary amount of metal will have flowed over the top of each ingot to prevent the formation of a pipe.

It is quite obvious that the amount of metal which must flow over the top of an ingot in order to make it pipeless will vary with the size of the ingot, the temperature of the metal, the rate of cooling, the composition of the steel, etc. In each mill the most desirable manner of conducting the overflow method will have to be ascertained by a few preliminary experiments.

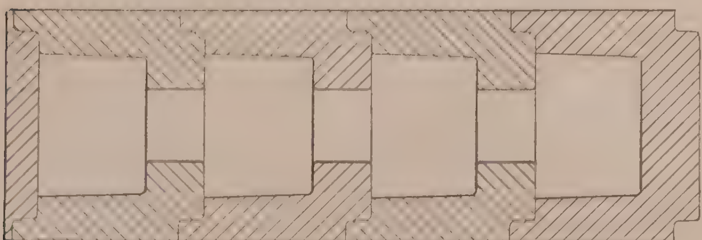


FIG. 6.

Connection between Molds.—A suitable connection between molds had to be devised, and this important point was finally solved with complete success by using the molds illustrated in Fig. 6. They will be seen to be three-sided molds, each mold moreover being in two sections for convenience in stripping When these molds are properly assembled and fastened together, each two adjacent molds have a common wall between them, at the upper part of which a groove is provided for the overflowing of the metal from one mold into the next. These molds have given very good satisfaction. They are, if anything, less expensive than the ordinary style of molds used in crucible steel manufacture.

Teeming.—It was found undesirable to teem directly into the molds, as in doing so the metal is agitated to too great a depth

during the teeming to allow of the quiet, undisturbed, cooling desired. To avoid this disturbance caused by the fall of the metal into the mold, a receptacle was used, shown in Fig. 7, and which consists of a crucible-like appliance provided with a false bottom. Each bottom is provided with one hole of suitable size. This crucible rests upon the mold into which it is desired to teem and the steel is poured into it in the usual manner. The metal flows into the lower chamber and from it into the mold. The relative sizes of the holes are so regulated that the lower chamber is being constantly drained. In this way the fall of the metal is broken and the steel in falling into the mold produces very little agitation of the molten top.

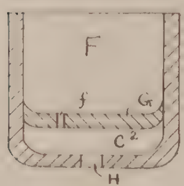


FIG. 7.

The Overflow Method and the Casting of Bessemer and Open-hearth Steel Ingots.—It was quite natural to first apply the method to the casting of crucible-steel ingots, but experiments are now under way to ascertain its value in casting Bessemer and open-hearth steel ingots.

We desire to express here our warmest appreciation to the management of the Simonds Manufacturing Company, which not only allowed the tests to be made in their mill, but rendered us invaluable services through their intelligent co-operation and good will. We are especially indebted to Mr. Daniel Simonds, President of the Simonds Manufacturing Company; to Mr. L. E. Howard, Superintendent; to Mr. W. C. Bird, Chemist, and to Mr. W. G. Merriman, Superintendent of the steel mill.

DISCUSSION.

JAMES CHRISTIE.—In dealing with the subject of piping and porosities, it is an open question whether it is more practicable to prevent these cavities in the ingots or to close them after they have been created. Mr Christie.

In the early days of Bessemer steel, when ingots were all pressed or hammered, we heard nothing of faults in finished material due to the existence of cavities in the ingots. Nowadays, when ingots of large section are hastily passed through the blooming mill, we are well aware that the most powerful mill has little effect in solidifying the ingot. The question arises—and I have been suggesting it for many years—should we not have a squeezing process as a preliminary to the rolling? A powerful press that would bear the same relation to the blooming mill that the squeezer did to the puddle mill, and which, by a couple of alternate compressions, would thoroughly solidify the material and convex the ends of the ingot before it passes into the mill. Such a press and operation would not cause delay or reduce the output of material. Its expense would be the interest on the machine and the cost of operating it. The advantages would be solid ingots and less loss from croppings and discards. This compression would have a tendency to break coarse crystallization resulting from the casting heat; and it is probable that by some such treatment we would hear very much less of faulty structures in finished bars of large section.

The interior of the ingot as it enters the blooming mill is usually in a plastic or semimolten condition, and in this condition of the interior there would probably be little trouble in welding up cavities under the compression above proposed.

ALBERT SAUVEUR.—A few words in reply to Mr. Christie's remarks. First, as to the old English rails to which he has referred, I believe those were low carbon rails; most of those early steel rails were very low-carbon rails, and it is well known that a low-carbon steel does not pipe by any means as much as a Mr. Sauveur.

Mr. Sauveur. medium high carbon steel. I had in mind more especially the case of rails of medium high carbon steel and I should like to confine my remarks to that class. We all know that the present tendency is to increase the carbon in rail steel, and therefore the tendency of piping also becomes greater. As to Mr. Christie's remark that in order to close the pipe it is only necessary to exert enough pressure, I must take exception to that statement. Those who have looked carefully into the matter know that high carbon steel will not weld, no matter how much pressure may be applied. The pipe may be closed, but its walls will not weld. If such a steel be subjected to an etching test, I am confident that the trace of the pipe would be revealed.

Mr. Whiting. JASPER WHITING.—The reason why piped ingots will not weld under the hammer is because an oxide is formed by the action of the air on the molten steel within the pipe. I might say further, in reference to Mr. Christie's remarks, that the drawing (Fig. 1) is, I believe, a reproduction of a photograph taken of an ingot of the same composition as that shown in the photographs (Fig. 5), where the pipe is seen to have been eliminated.

Mr. Martin. E. H. MARTIN.—While there may be more or less of a cavity at the top of any cast ingot, I do not believe that in good Bessemer steel practice an ingot cast at normal temperature ever has as bad a pipe as that in the illustration (Fig. 1) exhibited by Mr. Sauveur. I should like to ask the speaker to tell us something about the condition of the outer surfaces in the smaller ingots (Fig. 5).

Mr. Sauveur. MR. SAUVEUR.—At first we had some trouble in getting ingots with smooth sides, as the stream of metal in flowing from one mold into the next had a tendency to strike against the opposite wall which, of course, produced a rough side; but by properly shaping the groove between the walls we succeeded in deflecting the flowing metal so that it took the right direction, falling exactly in the center of the molds.

Mr. Martin. MR. MARTIN.—Unless the initial temperature of the metal be very high, I should think the metal would become too cold and "stick" at the last.

Mr. Sauveur. MR. SAUVEUR.—That would be the case if you should try to extend the process too far. It is merely a question of limiting it to whatever number of molds will give smooth-sided ingots.

MR. MARTIN.—What is to prevent the burning of the sides of the molds by the constant pouring of the metal? I refer especially to the first two molds. With the constant stream of hot metal passing over them would you not find what we call "stickers" at the top? Mr. Martin.

MR. SAUVEUR.—These experiments were made with three-sided molds, made in two sections. Mr. Sauveur.

MR. MARTIN.—Did you find that you could pull them apart? Mr. Martin.

MR. SAUVEUR.—We had no trouble whatever when we devised the right kind of mold. The application of the process to open-hearth and Bessemer ingots is now being worked out. Mr. Sauveur.

MR. MARTIN.—I tried the same thing with 0.35 carbon steel in 1890, and my experience was that the first three molds would stick together at the top, and while I obtained comparatively solid ingots, I could not use them because they were practically all in one mass. Mr. Martin.

MR. SAUVEUR.—I want to confine my remarks to small, crucible steel ingots. A little later I may have something to say concerning the casting of open hearth and Bessemer ingots. Mr. Sauveur.

MR. MARTIN.—I do not believe you could get large ingots with smooth surfaces; and rough surfaces would be just as bad as the pipe, because you could not get smooth bars from such ingots. Mr. Martin.

THE PRESIDENT.—May I be allowed just a word? It has been a favorite thought of mine for many years in studying steel, that one of the difficulties in making steel such as is shown by this ingot, is probably augmented, if not in a measure caused, by a certain peculiarity which Mr. Christie mentioned, namely, the speed of working. One of my old teachers used to say to me two things: First, "Chemical reactions do not take place unless substances are in contact"; and, second, "Time is an element in all chemical reactions." No one will deny that the Bessemer process of making steel is full of chemical reaction, and if I am right there is in the bath at the end of the blow a large amount of oxide of iron, produced during the blow. The final additions of manganese and carbon are supposed to remove that oxide, but my query is whether time enough is allowed, after the final additions are made, for the deoxidizing material to get in contact with the oxides? If we could by chance or in any way get a little more The President.

The President. interval between the final additions and the ultimate solidification of the metal in the mold, I believe many of the difficulties of making steel would partially, at least, disappear. I cannot help believing that the failure to close up and weld is due, in part at least, to oxides, and that the rails which Mr. Christie spoke about, of the old English steel, which were solid and good, and which he thinks were produced possibly by squeezing under the hammer, were more slowly made and therefore better steel. My solution for the bad tops of ingots is more time after the final additions are made, until the metal becomes solid in the mold.

Mr. Sauveur. ALBERT SAUVEUR.—Just a few more words as to this piping. Apparently the ingots which we use for rail making have no pipes at all, or if they have a pipe it is quickly closed and does no harm. I may have been mistaken in my views; but it is hard for me to believe this. Ingots which Mr. Martin has spoken of have so little pipe as to make this one look very large in his eyes. According to Mr. Christie, the pipe does very little harm because it can be closed up. Nevertheless, we know from experience that it does a great deal of harm. If it be thought that the pipe does not do any harm, there surely should be no objection to have a first-rate test of the matter. If it be claimed that the first rail from an ingot contains no pipe at all, by all means let us test that particular rail.

NICKEL STEEL: ITS PROPERTIES AND APPLICATIONS.

By Albert Ladd Colby.

In 1899, in discussing the well-known paper of Mr. James Riley, the father of nickel steel, Mr. Snelus remarked that Shakespeare told them that they might find "tongues in trees, sermons in stones, books in running brooks, and good in everything," and those who had studied meteorites appeared to have overlooked the fact that the metallic meteorites consist largely of alloys of iron and nickel, the *practical applications* of which they were now for the first time becoming acquainted with, in alloys of iron and nickel produced by themselves. "He was ashamed that he, himself, had so long overlooked Nature's teachings."

While my search through the proceedings of scientific societies for the past eighty years shows that Mr. Snelus was a little severe in his criticism of his fellow-ironmasters, inasmuch as the advantages of alloying nickel with iron and steel have been known and acknowledged by many investigators over a long period of years, it is nevertheless true that Mr. Riley was the *first* to publish a series of practical experiments proving the valuable properties possessed by nickel steel, and pointing out many of its important applications.

In 1822, Stodart and Faraday published their experiments made at Sheffield in the alloying of nickel and iron. A little later Berthier made some similar experiments in France.

In 1830, Wolf, of Schweinfurt, Germany, put some nickel-iron alloys on the market, which he called "Meteoric Steels." They were damasked, and Liebig comments on their magnificent appearance in a note in the *Annalen der Pharmacie*, and states that this alloy is destined to be developed in the near future.

In 1853, Fairbairn published some experiments undertaken to determine the strength of some alloys of nickel and iron similar in composition to meteoric iron.

At the Exposition held in New York, in 1853, Philip Thurber exhibited several samples of nickel steels produced from a nickeliferous limonite.

In 1858, Sir Henry Bessemer made an experimental 3 per cent. nickel-iron alloy, with a view of making what he termed "Meteoric Iron Guns." He did not, however, pursue the subject, nor publicly refer to the matter until 1896.

Percy, in his *Metallurgy*, published in 1864, refers to experiments conducted by Richardson in his [Percy's] laboratory on nickel-iron alloys varying from 1 to 50 per cent. in nickel.

In 1870, Alex. Parkes, of Birmingham, took out several patents for the production of alloys of iron and steel.

In 1883, John Gamgee made nickel-iron alloys in Connecticut.

In 1884, A. M. Clark, of London, patented the manufacture of a malleable ferro-nickel.

In 1885, ferro-nickel was manufactured at Marbeau's Works at Montataire, France, under the supervision of Bertheault.

In 1887, highly carboniferous nickel steels were made experimentally at the Steel Works at Imphy, France.

In 1888 and 1889, several French and English patents for the manufacture of nickel steel, and its applications, were granted to Marbeau, Schneider, Riley and Hall.

It is therefore evident that the advantages of alloying nickel with iron and steel have been known for some time. The credit of making the first systematic series of practical tests on nickel steels belongs, however, to Mr. James Riley, then of Glasgow, whose elaborate paper on "The Alloys of Nickel and Iron" was read by him before the Iron and Steel Institute of Great Britain, on May 8, 1889. From a discussion of this paper it appears that J. W. Hall, of Sheffield, had been working on similar lines to Mr. Riley, but his results had not been publicly put on record. Mr. Riley's paper gave the impetus to the introduction of nickel steel in a commercial way.

Since Riley's practical and suggestive paper, the technical men of many steel works in France, Germany, Great Britain and America have made nickel steel, studied its physical properties, and have put it on trial for a wide variety of purposes. In this work they have been aided by consumers looking for a better material, by the scientists connected with the technical universities in each country, as well as other independent investigators.

MANUFACTURE OF NICKEL STEEL.

No detailed reference to the melting of nickel steel and its subsequent rolling, forging and machining is possible within the scope of this paper. As is well known, nickel steel is melted in both the acid and basic open-hearth furnace, in the Bessemer converter and in the crucible. From personal observation, the writer has found that the valuable properties of this special steel have been recognized and applied by the principal steel-makers of Great Britain and the Continent, as well as by several of the steel-melters of America. The physical constants of the metals, nickel and iron, are so closely allied, a fact proven by their occurrence in metallic meteorites, that no special precautions, other than those incident to good melting practice, are necessary during any of the above standard processes of steel-melting, in order to insure a *thorough mixture* of the nickel and iron in the manufacture of nickel steel of any desired percentage of carbon, and with or without the presence of special elements, such as chromium, manganese, tungsten, molybdenum, etc. This fact is of great practical importance, especially in such applications as armor plate, marine and stationary shafting and engine forgings, rails and bridge material, which necessarily involve the casting of large masses of this special steel. Precautions must be taken in the rolling or forging of nickel steels, and especially in their final heat treatment; the steels below 15 per cent. nickel are also somewhat more difficult to machine than simple steels of the same carbon content. These difficulties have, however, formed no serious barrier to its successful introduction for a wide variety of purposes.

PHYSICAL PROPERTIES OF NICKEL STEEL AS COMPARED WITH CARBON STEEL.

When the physical properties of nickel steel, as compared with those of carbon steel, are better known and more fully appreciated, the amount now used for the purposes for which it has already been successfully introduced will be considerably augmented and new applications will undoubtedly result. It is appropriate, therefore, to review some of the more striking phys-

ical properties, obtained as suggested by Snelus, by "following Nature's teachings and alloying nickel with iron."

Modulus of Elasticity.—The modulus of elasticity or "coefficient of elasticity" of such materials as steel, which have a well-defined elastic limit, is determined by dividing the tensile stress in pounds per square inch at any point in the test below the elastic limit, by the elongation per inch of length produced by said stress. The modulus of elasticity which may therefore properly be regarded as the measure of the *stiffness* of the material is remarkably constant in steel notwithstanding great variations in chemical analysis, temper, etc. Young's modulus is practically the same for both tool steel containing 1.40 per cent. carbon and for the mildest steel used in boilers. The modulus of elasticity of steel is, in fact, rarely found to be below 29,000,000 or above 31,000,000, and is generally taken at 29,500,000 or 30,000,000 in engineering calculations.

A prejudice exists against nickel steel in the minds of some engineers owing to items which have appeared in the technical journals that the modulus of elasticity is lower in nickel steel than in carbon steel. The fact is, however, that while the high nickel steels, especially those containing 20 per cent. nickel or over, do have a lower modulus of elasticity than carbon steel, nickel steels containing say 4 per cent. of nickel or less, such as are applicable for shafting, forgings, bridge construction, rails, etc., have the *same* modulus of elasticity as carbon steel, viz., in the neighborhood of 29,000,000 pounds per square inch.

In proof of this assertion, the writer could quote the result of many calculations of the modulus of elasticity of various steels, containing below 5 per cent. nickel, made from the detailed records of the physical tests published annually by the United States Army Testing Laboratory at Watertown, Mass., under charge of Mr. J. E. Howard, the accuracy of whose work is beyond question. Evidence could also be cited from the experiments of foreign scientists such as Mercadier, Wedding, Rudeloff and Guillaume, all of whom support the above assertion that the presence of 4 or 5 per cent. of nickel in steel has no appreciable effect in reducing its modulus of elasticity.

Tensile Strength and Elastic Limit.—If space would permit, a large amount of evidence could be cited to prove that nickel

steel is chiefly distinguished from simple carbon steel by its proportionately high elastic limit. Furthermore, if 3 per cent. nickel is alloyed with an open-hearth steel of 0.25 per cent. carbon, it produces a metal equal in tensile strength to a simple carbon steel of 0.45 per cent. carbon, but having the advantageous ductility of the lower carbon steel.

On low-carbon steels not annealed, the addition of each 1 per cent. of nickel up to 5 per cent. causes, approximately, an increase of 5000 pounds per square inch in the elastic limit and 4000 pounds in the ultimate or tensile strength. The influence of nickel on the elastic limit and ultimate strength increases with the percentage of carbon present; high-carbon nickel steels showing a greater gain than low-carbon nickel steels.

In short, the addition of nickel to steel raises the proportion of elastic limit to ultimate strength and adds to the ductility of the steel. This effect of nickel in increasing the ratio of the elastic limit to tensile strength, without sacrifice in ductility, accounts for the increase in the working efficiency of nickel steel over carbon steel; in other words, its increased resistance to molecular fatigue.

Elongation and Contraction of Area.—The comparison of the results obtained from a large number of tests cut from full-sized prolongations of forgings of both carbon steel and nickel steel, show that for a given tensile strength the presence of 3 to 4 per cent. of nickel increases the elongation and to a greater extent the contraction of area. On the other hand, comparing simple carbon steel and 3 to 4 per cent. nickel steel of the *same* carbon content, the nickel steels will be found to have from 35 to 40 per cent. greater tensile strength, with practically the same elongation and contraction of area as the simple carbon steel. This increased ratio in the nickel steel, of ductility to elastic limit and tensile strength, is another index of its increased value over carbon steel for purposes where in service the material must resist severe and sudden shocks or rapidly repeated alternating stresses.

Effect of Compression.—The exhaustive series of experiments made by Wedding and Rudeloff show that the resistance to compression of nickel-iron alloys increases steadily with the per cent. of nickel present, until 16 per cent. of nickel is reached. Hadfield has also made a very complete series of experiments

on the resistance of nickel steel to compression. He has found that a steel containing 0.27 per cent. nickel shortened, under a compression of 100 tons (224,000 pounds) per square inch, 49.90 per cent. in a length of 1 inch; a steel with 3.82 per cent. nickel shortened 41.38 per cent.; with 5.81 per cent. nickel, 37.76 per cent.; and with 11.30 per cent. nickel, only 1.05 per cent. He states that an ordinary mild carbon steel without nickel, under similar conditions, would be shortened 60 per cent. to 65 per cent. He also states that the increased resistance to compression of nickel steel is not due to its *hardness*, an important point in the practicable application of nickel steels where machining is necessary. He argues that the toughening action of nickel when added to steel is caused by a very intimate combination of the molecular structure, and that this advantage is further enhanced by the fact that the nickel does not show a disposition to segregate in steel like other elements; in other words, it appears to be more intimately combined.

A striking illustration of the ability of nickel steel to resist compression was exhibited to the writer in 1900 by Holtzer & Co. A cylinder 7.87 inches in height, 6.97 inches external diameter and walls of 0.73 inch in thickness, cut from a nickel-steel gun hoop, was compressed by a load of 886 gross tons down to a height of 4.72 inches. The internal fibers were thereby extended 46 per cent., and without the formation of any cracks.

Rigidity.—The superior *stiffness* of nickel steel over carbon steel without any sacrifice in its *toughness* has been proved in numerous applications coming under the writer's observation; this combination of properties forms one of the strongest arguments in favor of the use of nickel steel for a wide variety of applications where the service demands a rigid, as well as a strong, elastic and tough material. H. A. Wiggin states that in his experience he found that nickel steel under the drop test gives better results than carbon steel, even in a greater ratio of superiority than exists in the comparison of the tensile tests of the two steels.

J. G. Eaton made a comparative test of nickel-steel plate and carbon-steel plate, with a view of subjecting both plates to the same strains as those experienced by bottom plating. Both plates were riveted to angles in a manner intended to imitate

the riveting of a ship's plate between the frames. A round-faced punch placed on each plate was then struck by a heavy falling weight. Each plate endured thirteen blows before rupture, and at the next blow each plate showed a clear aperture; that in the carbon-steel plate, however, was $23\frac{1}{10}$ square inches in the clear, while the aperture in the nickel-steel plate was three-quarters of a square inch; a ratio, therefore, of 30.5 to 1 in favor of nickel steel.

D. H. Browne states that a 3 per cent. nickel steel shows about 48 per cent. greater stiffness and 45 per cent. greater toughness than carbon steel; the word "stiffness" referring to the amount of deflection produced by the blow, while the word "toughness" refers to the number of blows required to produce the rupture.

Cold and Quench Bending Test.—Nickel steel will resist bending both before and after quenching better than carbon steel of similar tensile strength. This has been strikingly illustrated in a long series of practical tests made on nickel-steel plates by Mr. Beardmore at his Parkhead Steel Works at Glasgow, Scotland. These tests included quench bends, cold bends, and also cold-bending tests of the nickel-steel plates with holes drilled in the tests prior to the bending. The results of Hadfield's careful experiments on the bending properties of cast and forged nickel-iron alloys, varying from 0.27 to 49.65 per cent. of nickel, may be summarized in his statement, "that from about 2.50 to about 6 per cent. nickel the bars certainly showed greater bending angles than those of any other iron alloys experimented on," by him.

In a series of comparative tests of carbon steel and nickel steel, such as is used for forgings, made at the works of the Bethlehem Steel Company, the writer obtained bending tests on the unannealed, annealed and oil-tempered nickel and carbon steels which show the superiority and freedom from brittleness of the nickel steel. The accompanying photograph was made of the mounted test specimens; it gives the photomicrographs of both kinds of steel under the different conditions of heat treatment. A comparison of the physical properties of the two steels is as follows:

Heat Treatment given to each Steel.		Tensile Strength. Lbs. per Sq. Inch.	Elastic Limit. Lbs. per Sq. Inch.	Elongation Per Cent. in 2 Inches.	Contraction of Area. Per Cent.
Annealed . . .	Carbon Steel	109 500	51 440	19.50	30.31
	Nickel Steel	100 330	66 720	25.00	54.50
Oil-tempered	Carbon Steel	129 360	67 230	17.50	38.53
	Nickel Steel	103 890	76 390	25.00	61.50

Hardness of Nickel Steel.—It has been definitely proved that a very low-carbon steel cannot be made hard by the mere addition of nickel. Nickel steel is tougher than carbon steel, but is not *harder* in the true meaning of this latter term.

The hardness of nickel steels, below about 15 per cent. of nickel, depends upon the proportion of nickel and carbon jointly. Thus, while a steel with 2 per cent. nickel and 0.90 per cent. carbon cannot be machined, a steel with 3 per cent. nickel and 0.60 per cent. carbon can be machined. The freedom from *hardness* of comparatively low-carbon nickel steel is strikingly illustrated by the writer's experience in cutting with a penknife the rifle barrels made at Bethlehem of steel containing 4.50 per cent. nickel and 0.30 per cent. carbon, and yet this steel had an elastic limit of over 80,000 pounds and a tensile strength of over 100,000 pounds per square inch.

At 20 per cent. of nickel, as stated by Riley, successive increments of nickel tend to make the steel softer and more ductile, and even to neutralize the influence of carbon.

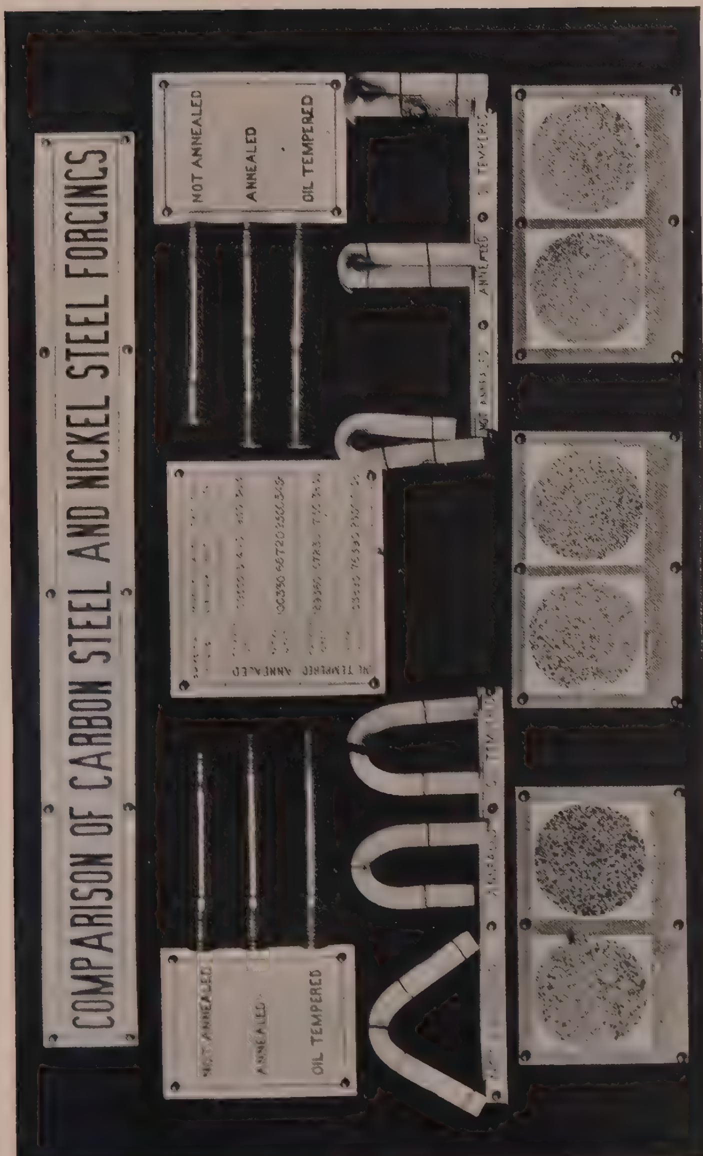
Resistance to Torsion.—Nickel steel resists torsion or twisting stress better than the same class of carbon steels.

Riley's experiments indicate that it is not necessary to use steels high in nickel to obtain the best effect in torsional resistance.

The writer has found that several of the French steel works have appreciated this property of nickel steel by applying it for the manufacture of special wire and springs.

Resistance to Wear or Abrasion.—The rigidity and toughness of nickel steel makes it a desirable metal where, in service, the material is subjected to wear or abrasion.

PLATE III.
PROC. AM. SOC. TEST. MATS.
VOLUME III.
COLBY ON NICKEL STEEL.



This has been proved in practice by a comparative trial of nickel-steel and carbon-steel rails on sharp curves on the Pennsylvania lines. About five years ago 50 tons of nickel-steel rails were laid on a 4-degree curve near New Salisbury, of the Cleveland & Pittsburg Division of the Pennsylvania lines. In June, 1899, the Pennsylvania Railroad placed an order with the Carnegie Steel Company for 300 tons of nickel-steel rails. These were laid in the "horseshoe" curve, west of Altoona. The results of these trials indicated that the life of a nickel-steel rail was at least three to four times greater than that of a carbon-steel rail. This increased resistance to wear and abrasion has resulted in the sale, by the Carnegie Steel Company, of some 10,000 tons of nickel-steel rails, to be laid mostly on curves, on the Pennsylvania lines, the Baltimore & Ohio, the New York Central & Hudson River, the Bessemer & Lake Erie and the Chesapeake & Ohio Railroads.*

Further evidence of the value of nickel steel to withstand abrasion is found in the results of experiments carried on by one of the French railroads in the trial of nickel steel for locomotive tires.

Expansion of Nickel Steel.—The coefficient of expansion of nickel steel varies greatly with the percentage of nickel present, especially in the series of nickel steels containing from 20 to 45 per cent. of nickel. The 36 per cent. nickel steel, called in France "Invar" (from the word "invariable"), has a lower coefficient of expansion than any other metal or alloy known.

Guillaume, of the International Bureau of Weights and Measures, the best authority on this subject, and whose opinion is also supported by other experts, states, however, that there is no practical difference between the expansion of simple carbon steel and of steel containing up to 5 per cent. of nickel. In the use, therefore, of low-carbon 3 to 5 per cent. nickel steels in bridge-construction, the same allowance for expansion can be made as when carbon steel is used. This is an important point, especially when both carbon steel and nickel steel are to be used in the same structure.

The different coefficients of expansion of steels, containing

* See remarks of Messrs. John McLeod and C. B. Dudley, pp. 156 and 158.

from 30 to 45 per cent. of nickel, have resulted in their application in France and Germany for a wide variety of purposes, which will be referred to later.

Effect of Punching and Shearing on Nickel Steel.—Beardmore, the Scotch steel-maker, after an elaborate series of tests, places the loss of strength due to punching ordinary mild steel at 33 per cent. of the original strength, and claims that the loss of strength in punching nickel steel varies from 15.5 to 20 per cent. of the original strength, and, furthermore, that on thicker sections of nickel-steel plate the loss of strength is only about 10 per cent. A number of other experimenters have also found that nickel-steel plates are not weakened by punching to as great an extent as carbon-steel plates.

There is ample evidence that the presence of nickel in steel increases its shearing strength. This is important, especially in connection with riveted work, as the strain on the rivet is not a simple strain, but rather a shearing or cutting action. Moreover, in the shearing of nickel-steel rivets, the fracture is fibrous and the metal appears to have torn gradually, whereas in ordinary carbon-steel rivets the metal breaks off short.

From the results of a comparative test made at Bethlehem on nickel-steel and carbon-steel rivets, the conclusion was drawn that it may be safely deduced that a $\frac{3}{4}$-inch nickel-steel rivet will replace a $1\frac{1}{16}$-inch or even possibly a $1\frac{1}{8}$-inch common steel rivet, thus effecting a saving of considerable plate section and giving increased strength.

Experiments made by Beardmore, Abraham, and Rudeloff, and at the Creusot Steel Works, also testify to the increased shearing strength of nickel-steel rivets.

Experiments made by the Société Denain and d'Anzin prove that 5 per cent. nickel-steel rivets possess over twice the shearing strength of iron rivets.

Browne states that the sheared edges of carbon-steel plates often cut ragged, whereas nickel-steel cuts clean.

Segregation: The segregation of nickel itself in steel, and the effect of its presence in checking the segregation of the metalloids in steel.—The writer's opinion, based upon a large number of chemical analyses made at Bethlehem, is that nickel in itself segregates but very slightly, even in large armor plate and shafting

ingots. This is natural, as the atomic volume, atomic weight, and specific gravity of nickel are similar to those of iron.

Some experimenters testify that nickel tends to check the segregation in steel of the other elements such as sulphur, phosphorus, carbon, manganese, and silicon. Mr. Hadfield thinks that the tendency of nickel to check segregation is probably due to the fact that it raises the melting-point of the carbides or cementing material and causes the whole mass to set more nearly together, and quotes in proof that nickel-steel ingots have a finer grain than carbon-steel ingots. Mr. Chase, of the Midvale Steel Company, states that "nickel is supposed to lessen the segregation and liquation of carbon by combining with the carbon which cements the particles of iron together, and thus bringing the specific gravity of the carbon compounds nearer to that of the rest of the alloys in the fluid mixture. It also seems to cause this cementing carbon to solidify at more nearly the same temperature as the other alloys."

Mr. Campbell, of the Pennsylvania Steel Company, made a series of tests to prove what he states to be the current impression among manufacturers of nickel steel, that the presence of this element prevents segregation. His conclusion is that there seems to be good ground for the assumption that nickel prevents the separation of the metalloids, but that it does not prevent it altogether, and he states that it is not probable that any other agent will ever be found competent for this task.

Within the limits of this general review, it is impossible to refer in detail to the interesting subjects of the heat treatment, the critical points, the molecular relation of nickel to iron and carbon and the microstructure of nickel steels; the effect of extreme temperatures and the electric and magnetic properties particularly of steels containing over 20 per cent. of nickel.

Sufficient evidence has, however, probably been presented to prove that nickel steel possesses many advantages of practical importance over simple carbon steels, and the engineer looking for a trustworthy material will be convinced by what has been presented that it is safe to give nickel steel a practical trial.

In the preceding pages the writer has shown that alloys of nickel and iron have long been made, and that their principal physical and chemical properties have been carefully studied. He now proposes to briefly summarize the *applications* of nickel

steel which have come under his personal observation, hoping thereby to convince the engineer who looks upon nickel steel as a new material, that he is warranted in giving it a trial owing to the success which has already attended its practical trial, at home and abroad, for a wide variety of purposes.

APPLICATIONS OF NICKEL STEEL.

The advantageous physical properties of nickel steel over carbon steel just briefly reviewed cannot fail to suggest numerous applications where this special steel is of decided practical advantage and where the demands in service amply warrant its somewhat increased cost.

That the properties of this material have been fully appreciated in some instances is proven by the large number of purposes to which it has been applied both in this country, in England and on the Continent.

Within the limits of this paper the applications for nickel steel which the writer has found during the past year's special study of this subject can be but briefly summarized.

As is well known, the advantages of nickel steel for *armor plate* have been recognized for some years, so much so that nickel steel, with or without chromium, is now used entirely by the manufacturers of armor plate in all countries. It is used also for the manufacture of *ammunition hoists*, *communication tubes* and *turrets* on battleships, for *gun shields* and for *armor-plate bolts*, and also for the large *safe-deposit vaults* made of Harveyized nickel-steel armor plates.

Nickel steel is used for a wide variety of *forgings* and *drop forgings*, including the axles and certain other parts of automobiles, marine-engine forgings, shafting and crank shafts for government and merchant marine, stationary-engine forgings and shafting and locomotive forgings; the latter including *axles*, *connecting-rods*, *piston-rods*, *crank-pins*, *crossheads*, *links*, *link-pins*, and *pedestal cap bolts*. Also for forged *piston rods* for steam hammers and rock drills, sea-water pumps, stationary engines, etc.

It has been applied for the manufacture of *axles* not only for automobiles and locomotives, but for electric, passenger and freight cars, field-gun carriages, etc.

The advantages of nickel-steel *castings* are also being generally recognized. Test specimens cut from coupons from annealed nickel-steel castings can be guaranteed to show an elastic limit of 50,000 pounds, as determined by an electric micrometer, with an elongation in 2 inches of at least 18 per cent. In some locomotives now building, nickel-steel castings have been used for all of the following parts: *Frames and rails, driving wheel centers, driving boxes, driving cellars, drawhead pocket, rocker shaft, guide yoke knees, eccentric straps, equalizing beams, reverse shaft, cross-ties, lifting links and crossheads.*

Nickel-steel castings have also been introduced for large *hydraulic cylinders* and for the *crank webs* of shafting, for *propeller blades, rudders*, large *pinions, gearing* and *gear-wheel blanks*, and also for *plate rolls*.

Rolled nickel steel in the form of rounds, billets, flats, etc., has received a wide variety of applications, including *bolts, locomotive stay bolts, pedestal cap bolts, rivets, bicycle chains*, holding down *bolts* for *gun mounts* and other parts of ordnance.

The application of nickel steel for *rails* and *splice bars* has already been referred to. It is about to be applied in this country for the manufacture of locomotive *tires*. It has been successfully tested abroad for this purpose, both in England and in France, and also for the manufacture of *frogs* and *switches*.

There is little doubt but that in the near future nickel steel will enter into *bridge construction* and for certain *structural purposes*. Its properties are especially attractive for long-span bridges and also in cases where the element of freight enters so largely into the cost of the structure as to make lightness in construction a desirable factor.

Besides armor plate, nickel steel has been used to a considerable extent for *deck, hull* and *ship plate*, and it has been widely used abroad, especially in France, for *artillery plate*, including the plates used in the construction of ammunition wagons, artillery boxes, cartridge boxes, etc. It is about to be tried for locomotive *fire boxes* and *boiler plate*, and these results will be watched with considerable interest. It has also been used abroad for *air reservoirs* for torpedo boats, and for *tanks* for compressed oxygen, carbonic acid, hydrogen, etc.

Nickel steel enters into the construction of *ordnance* to a

considerable extent, especially abroad, including gun forgings, rifle barrels and small arms, revolvers, gun shields, powder tubes, projectiles, shrapnell, shot, shells, etc.

In the form of wire, nickel steel has received many applications, including resistance wire as a substitute for German silver, wire cables for wet mines, *torpedo defense netting*, *electric lamp wire* as a substitute for platinum wire, *umbrella wire*, *corset wire*, and also a large number of special applications where the desired property is a low coefficient of expansion, such as wire used in the manufacture of *armored glass*, in the *mounting of lenses*, mirrors, level tubes, etc., and for balances for clocks, *measuring rods*, *surveying tapes*, *rules*, *pendulum rods*, *thermostats*, *rheostats*, *weighing machines*, *circuit breakers*, etc.

High-carbon nickel steels have also been introduced to a considerable extent abroad for special *springs*, both in the form of wire and flats. Quite a number of *tool steels* on the market, especially the foreign steels, contain a certain proportion of nickel. Nickel steel is also used for *dies*, *taps*, *set screws*, *cutlery*, *tableware* and *harness mountings*.

Some of the lower nickel steels when drawn into *tubes* furnish a very stiff material with an elastic limit of about 100,000 pounds, applicable for all sorts of machine construction where strength and lightness must be combined. The field for this application of nickel steel is a wide one, and after a few manufacturing difficulties have been overcome, this class of tubing will be placed on the American market.

One of the most promising applications for high nickel steel is for non-corrosive seamless tubing for *automobile boilers*, *locomotive boilers*, *stationary boilers*, *marine boilers*, and *marine condensers*, and for *gas engine hot tubes*. This tubing has recently been introduced on the American market by the Shelby Steel Tube Company. It is manufactured from a 30 per cent. nickel steel of domestic manufacture. The increased initial cost of these high nickel steel tubes is fully offset by the following advantages:

1. Obtaining a practically non-corrosive tube, thus avoiding the expense of the frequent renewals due to the "pitting" of both iron and low-carbon steel tubes.

2. Increasing strength over iron and steel tube, thus allowing, without risk, the use of a tube of *lighter* gauge, which insures

a saving in the original weight and cost, as well as an increase in steaming efficiency.

3. These tubes, when they finally are taken out of boiler, can be sold to steel companies making nickel steel, at the market price of steel tube scrap, plus about twenty cents per pound for the contained nickel.

CONCLUSION.

It will probably be a surprise to many, to note from the above summary the wide variety of purposes for which nickel steel has been already successfully applied. The United States is perhaps in the lead in the applications which have been made of 3 to 4 per cent. nickel steels. France is undoubtedly in the lead in the applications of the higher nickel steels.

The wide range in physical properties of steels containing from 2 to 45 per cent. nickel, and the variations in each grade resulting from different carbon content, or the presence of some special element such as chromium, molybdenum, tungsten, etc., makes the study of the alloys of nickel, iron and carbon imperative to the engineer in search of a safe material with an exceptionally advantageous combination of physical properties.

It is hoped that this brief and imperfect review of the physical properties and applications of nickel steels will awaken an interest among engineers and consumers in this alloy made by combining the elements, iron and nickel, so closely allied in their physical properties, or, as Suess has told us, "made by following Nature's teachings."

DISCUSSION.

Mr. McLeod.

JOHN McLEOD.—Our President has requested me to open the discussion on this subject, Nickel Steel. I think it is a fact that has been noted by all the members of this organization who have been members two or three years, that each year has brought to this body new problems to solve. This body is rather complex, being composed of engineers and representatives of manufacturers and consumers. I know from my own experience that there have been each year new demands on the engineer made by the consumer, and in turn by the engineer on the manufacturer. The manufacturer asks engineers for ways and means of meeting new conditions. I know that in the different machines at our own mills there have been found parts that have failed from time to time. We have endeavored to meet these failures by changing the grade of steel from soft to hard. When we continued to have trouble we commenced to increase the sections, and still meeting with trouble from breakages, we finally resorted to the use of nickel steel with most satisfactory results. Up to the present we have found great relief in not having had further breakages, which to a mill man, you know, means expense; and expense always means annoyance.

In the matter of the uses of nickel steel I think there is much yet to learn. There have been but few phases of this question which we feel have been, even in a measure, demonstrated. I think, however, we can say as manufacturers, and I think that some at least of the engineers will agree with us, nickel steel when used as a metal to oppose abrasion is certainly much superior to the plain carbon steel used heretofore. This has been in a measure demonstrated by a trial of nickel steel rails on the part of a railroad company.

The verdict has been—and the verdict is that of the railroad, not of the manufacturer—that the nickel steel rails furnished outwore four carbon-steel rails such as would have been furnished under the current specifications for that particular point on that

Mr. McLeod.

particular road. However, the Engineer of Maintenance of Way of that road stated that he felt the manufacturer, in his attempt to make a rail which would resist abrasion, had gone possibly a step too far; that the rails in question were probably a trifle harder than he would care to recommend. He said that advisedly. The rails themselves, as I understand, have not given any particular trouble on account of their hardness. The indication of their hardness was due to accident when the rails were received. Since that time the same railroad company has deemed it advisable to go a step farther, and, instead of treating this matter in a purely experimental way, has ordered five thousand tons of nickel-steel rails and expects to get results which will warrant the expenditure. These rails, however, will be simply the carbon-steel rails as at present ordered by the average railroad of the country with an addition of nickel. In the matter of rails, there has been a tendency, possibly, to introduce too high a carbon with the nickel addition. On the other hand, I think that in many cases where nickel steel has been substituted for carbon steel, the attempt has been to lower the carbon when introducing nickel, and to produce a steel which in point of strength is not very far removed from the original carbon steel used for that particular purpose. I believe that this is a mistake. I think it is unfair to the nickel steel, for the reason that nickel is added to improve a product under known conditions, and therefore we should not depart from those known conditions.

The subject is an interesting one, I think, to all of us. I believe that all of the engineers present, and many of the consumers, have been plagued with annoying breakages. Breakages generally mean not only the annoyance of delay, but the annoyance of expense and sometimes something more serious than annoyance, namely, loss of life. If this discussion should lead to the introduction of better material for certain purposes, I think that we shall be well repaid for all the trouble which has been expended on this meeting. I should, therefore, like to ask all the members present who have knowledge of and interest in this subject to treat the matter seriously, because I know that most of the manufacturers of the country share your interest and are prepared at any time to incur almost any reasonable expense to help you solve a problem which is certainly a vital one.

The President.

THE PRESIDENT.—Gentlemen, I have not very much to say about nickel steel. With us, nickel steel is in its trial stage and the trials are not yet very extensive. As far as we may be said to have reached any conclusion in regard to the value of nickel steel, it may perhaps be summed up in this: That where metal is to be subjected to abrasion there is little doubt about the value of nickel steel. As a concrete example I may say that some three or four years ago perhaps a half mile or more of nickel-steel rails were put upon the Kittanning Point curve just west of Altoona, a nine-degree curve, one of the hardest curves on the road. The rails were put in the No. 3 west-bound freight track. In that location the ordinary carbon-steel rails as they are now made last about ten months. The nickel steel rails have worn a little over three years, and this spring these rails were taken out of their location and moved down to the straight line in the same track to give place to some new nickel-steel rails. They were removed not because they were regarded as worn out—although, as I will state in a moment, there were some defects—but to give a chance to try some new orders of nickel steel rails. The defects that have thus far appeared, so far as these rails are concerned, were a little tendency for a part of the head to drop off. I do not know that I can explain to you exactly what is meant, but on certain parts of the rail alongside of the head a part of it breaks and drops off. I have some pieces in the laboratory now that have broken off. It is a fault that is characteristic sometimes of carbon-steel rails, and is apparently connected in some way with the pipe in the ingot. On the other hand, the rather remarkable, and I may say more, the wonderful behavior of the metal under abrasion under the conditions which I have named, as you see, three times better than carbon rails in the same location, and possibly even better than that, is something that gives us very great hope and encouragement. We are now planning to put some nickel steel into tires. As has been stated by the author, this has already been tried abroad.

Perhaps this is the place to give you a single thought in regard to a distinction which we make in railroad work. In places in our constructions, abrasion, that is loss of metal by wear, is the great and important matter. Things wear out and must be replaced, due to this fact, and this replacing of parts that have become

worn in service, which wear is due to abrasion, is one of the large items in the operating expenses of railroads. In other places, parts of the structure fail, not due to abrasion, but due to breaking, the breaking being caused by repetition of stress. You are all familiar with Woehler's law, which in brief may be stated, that any piece of metal subjected to strain a sufficient number of times will sooner or later fail. Our most common illustration of failure is the car axle, which, as is well known, is subjected to alternate tension and compression with each revolution. If the fibre stress is high enough and the number of revolutions great enough, our idea is that sooner or later every axle will fail. The same may be said of piston-rods, of crank-pins, of locomotive frames, and, indeed, many other places might be cited where the parts of the structure are subjected to alternate bending or tension and compression stresses. The President.

Now in regard to the behavior of nickel steel under these varying stresses we are still in doubt. From what Mr. Colby has just stated, it would almost seem as though, under alternate stresses, nickel steel would behave better than carbon steel, and we have some data that point in this direction. We have ten nickel steel piston rods in service opposite ten carbon-steel piston rods on the same locomotives. One of the carbon-steel piston-rods has been drawn, and thus far none of the nickel-steel piston rods, although they have been in service now over a year. On the other hand, we know of nickel-steel piston-rods which have failed after very short service; so that we are in doubt, as said above, as to the behavior of nickel steel under alternate stresses.

This is hardly the place to discuss that very large question, as to what physical properties are characteristic of a steel that best resists alternate stresses, but thus far all our experience seems to indicate that the most successful resistance is given by the stiffer steels. If this be true, it would seem that possibly a little higher carbons than are characteristic of many of the nickel steels would be desirable, and it is entirely possible that if this modification is introduced a nickel steel may be found which will more successfully resist alternate stresses than carbon steel.

CHARLES WHITING BAKER.—Might I ask Mr. Colby: Has the lubrication of nickel steel been investigated to find whether Mr. Baker.

Mr. Baker. its very close texture causes any greater tendency to the heating of journals made of it than of ordinary carbon steel?

Mr. Colby. ALBERT LADD COLBY.—I am glad Mr. Baker raised this point. In a series of tests, on a special machine designed for the purpose, it has recently been determined that the coefficient of friction of nickel steel is, if anything, less than that of carbon steel. The object of the test was to compare, under like conditions of lubrication and frictional resistance, nickel steel and carbon steel of the composition used for locomotive driving-wheel axles. In this special journal-bearing testing machine each of the two small test axles was of the same shape and size and carried fly-wheels of equal weight. After giving the two axles the same initial speed, the source of power was removed and the two axles allowed to spin until at rest, the number of revolutions and length of time being recorded. After the two axles of the machine had worn down to a proper bearing surface, it was found that under different conditions and with different kinds of lubricants the nickel-steel axle spun longer than the carbon-steel axle. The details of this test will doubtless be published later on, when all possible changes in lubricants and bearing surfaces have been included, but the result so far reached is, I think, quite natural, as the denser and finer structure of the nickel steel would tend to offer a less resistance to friction.

Mr. Mathews. JOHN A. MATHEWS.—I should like to ask Mr. Colby if nickel greatly lowers the melting-point of pure iron? In general almost all metals when alloyed have their melting-points lowered, and it occurred to me that in this we have an explanation of the decreased segregation which is said to characterize nickel steels. If such is the case, may it not be that segregation is lessened because the solidifying point of the iron-nickel system is brought nearer to that of the compounds with the metalloids contained in the steel, such as the sulphides and phosphides of iron and manganese—the whole mass solidifying within a narrower range of temperature than is the case in ordinary steels, with the result that less time is allowed for the migration of certain constituents to the center of the ingots. Nickel and iron in themselves are supposed to form perfect solutions; solid solutions which we should expect to be of a lower melting-point than either of the constituent metals.

MR. COLBY.—I have no data based on actual comparisons of the melting-points of alloys of nickel and pure iron with the melting-points of the metals themselves. The addition of nickel to steel does tend to check segregation, and this must be due to the nickel-iron alloys and the metalloid compounds becoming solid at more nearly the same temperature than when nickel is absent. Mr. Colby.

Mr. Mathews suggests that this narrowing of the range in temperature is brought about by a lowering of the melting-point of the nickel-iron alloys. Mr. Chase, of the Midvale Steel Company, has advanced the theory that the segregation in nickel steels is less than in carbon steels because the nickel raises the melting-point of the carbides or cementing material.

MR. MATHEWS.—I favor the theory that nickel decreases segregation by lowering the melting-point of the iron-nickel compound of the steel rather than by raising the melting-point of the other constituents, which is contrary to our knowledge of the behavior of mixed metals. Mr. Mathews.

MR. COLBY.—Whichever theory is adopted as to the comparative melting-points, the important fact should not be lost sight of that the injurious metalloids segregate less in nickel steel than in carbon steel. Mr. Colby.

G. W. THOMPSON.—I want to ask whether in the use of nickel-steel tubes in boilers there might not be electrolysis on account of the nickel in the tubes being electronegative to the iron or steel in the plates of the boilers? Mr. Thompson.

MR. COLBY.—No difficulties, due to electrolysis, have been experienced as yet by the French, Dutch, and German Navies who have had 25 per cent. nickel-steel boiler tubes under trial in their torpedo-boat boilers for the past three years. So far these nickel-steel tubes have proved satisfactory and in some cases have lasted three years in places where only a nine months' service of carbon-steel tubes was obtained. Mr. Colby.

MR. THOMPSON.—Electrolytic action would take place on the boiler plates or heads, not on the tubes. Mr. Thompson.

MR. COLBY.—The foreign trial referred to included the entire water-tube boiler made up of nickel-steel tubes and carbon-steel boiler plates and tube sheets, and so far no difficulty, due to electrolysis, has occurred. Should such be feared, there Mr. Colby.

Mr. Colby. is no reason why the plates and tube sheets could not be made of the same high-nickel steel as the tubes.

Mr. Whiting. JASPER WHITING.—What effect will 35 per cent. of nickel have on the critical point of steel?

Mr. Colby. MR. COLBY.—According to Osmond the presence of about 25 or 26 per cent. of nickel causes a marked lowering of the critical points of steel. In a steel sent to him by Mr. Hadfield, and containing 24.51 per cent. nickel and 0.10 per cent. carbon, Mr. Osmond found the critical points to lie between 40° C. and ordinary temperatures. Dr. Hopkinson found the transformation point of a steel containing 25 per cent. of nickel to be below 0° C. His steel probably contained more carbon than the Hadfield steel experimented on by Osmond.

In general the presence of nickel lowers the recalescent point of a steel of a given carbon content.

Mr. McLeod. MR. MCLEOD.—The use of nickel steel for boiler purposes has been referred to. In this connection I recall that the cruiser "Chicago" has a battery of boilers, part of which are made of carbon-steel plates and part of nickel-steel plates. These boilers have been in use for several years. Lieutenant Parks is here and he can probably tell us whether there has been any information obtained through the failure of either the carbon or the nickel-steel plates.

Mr. Parks. W. M. PARKS.—The "Chicago" is equipped in part with cylindrical boilers and in part with water-tube boilers. She has four cylindrical boilers about twelve to fourteen feet in diameter by eight to ten feet long. The shell of these boilers is of nickel steel, containing $3\frac{1}{2}$ per cent. nickel. I think there has been no report on these boilers; but as a rule the shell part of cylindrical boilers gives very little trouble. I do not know why that should be so, but it is a fact nevertheless. The tubes are the parts which give trouble. We have not yet been able to find a material for boiler tubes that is satisfactory. We have tried everything in the navy, charcoal iron, hot-drawn steel tubes, cold-drawn steel tubes, Bessemer tubes, open-hearth tubes, etc. We are now endeavoring to make arrangements to try 30 per cent. nickel-steel tubes. To illustrate the importance of finding durable material for boiler tubes, I may state that one of our ships was overhauled about a year ago, and the boilers refitted with new tubes of cold-drawn mild steel. These tubes lasted exactly nine months. That is an

extreme case, but we rarely have tubes, even of the very best quality, that will last more than three years. Mr. Parks.

MR. COLBY.—Supplementing Lieutenant Parks' remarks I understand that the $3\frac{1}{2}$ per cent. nickel-steel plates entered into the construction of one or more of the "Scotch" boilers of the U. S. S. "Chicago," which went into commission December 1, 1898. The test specimens cut from these nickel-steel boiler plates show a tensile strength of between 80,000 to 90,000 pounds per square inch and an elastic limit of between 50,000 to 63,000 pounds per square inch, with an extension in eight inches of over 20 per cent. Mr. Colby.

G. LANZA.—I should like to ask Mr. Colby for information as to the cost of 30 per cent. nickel-steel boiler tubes in comparison with mild carbon-steel seamless boiler tubes? Mr. Lanza.

MR. COLBY.—As the 30 per cent. nickel steel so far made in America for boiler tubes has been melted by the steel company with which I am connected, and as I have been associated with the Shelby Company in the manufacture of the tubes from this steel, I am in a position to give definite information in reply to Professor Lanza's inquiry. Mr. Colby.

At the price at which the Shelby Company have so far been able to purchase the 30 per cent. nickel-steel billets they find that they can put the finished nickel-steel tube on the market at about three times the price charged for a carbon-steel seamless tube of the same diameter and thickness. For instance, in the $1\frac{1}{8}$-inch and $1\frac{1}{4}$-inch boiler tubes used in a torpedo-boat destroyer the carbon-steel tube is sold for 15 cents per pound and the 30 per cent. nickel-steel tube can be offered at 45 cents per pound. It is, however, entirely practicable to use lighter gauges of the nickel-steel tubes, and this saving in weight, together with the fact that the nickel-steel tube will last at least two and one-third times as long as the carbon-steel tube, lowers the actual increased cost of the nickel-steel tube. In addition to this it must be borne in mind that when the nickel-steel tubes are taken out of the boiler they can be sold to any maker of nickel steel for the market price of nickel-steel tube scrap plus about 20 cents per pound for the contained nickel. In the final comparison of the net increased cost of nickel-steel tubes, the increased steaming efficiency, due to the lighter gauged nickel-steel tubes, and the saving due to

Mr. Colby. the less frequent re-tubing of the boilers, as well as the saving in weight of the boiler installation, should be given due consideration.

Mr. McLeod. MR. McLEOD.—Answering the inquiry just addressed to the chair for information as to the relative cost of nickel-steel rails and carbon-steel rails, I would state that the price of nickel-steel rails is twice that of carbon-steel rails, or, in round figures, $50 per ton, but a consideration of the question of salvage makes the comparison much more attractive. The gentleman will remember the statement of our President that the experimental nickel steel rails were in the track three years and then not removed because of their having worn out, but to give place to the new nickel steel rails just purchased. Assuming they were worn out, the carbon rails that would have been used at that point would have worn out in ten months, making the comparison in service more than three to one, or, in other words, it would have been necessary to have purchased $84 worth of carbon rails as against $50 worth of nickel-steel rails. But there is an additional salvage to be obtained from the value of the nickel in the scrap, which Mr. Colby places at 20 cents a pound. There being 3½ per cent. of nickel in the rails, or 70 pounds per ton, the salvage from this source would be $14 per ton, which deducted from $50 would leave $42, the net cost, as against $84 per ton for the carbon-steel rails. Credit should be allowed also for the extra cost of maintenance in the case of the carbon rails, which have to be removed so frequently.

Mr. Campbell. WILLIAM CAMPBELL.—I should like to ask Mr. Colby if the refining temperatures of nickel steel and carbon steel are the same for the same carbon content?

Mr. Colby. MR. COLBY.—Assuming that Mr. Campbell refers to the heat treatment necessary to "refine" and finish a forging or casting, so as to bring it into the best possible physical condition for service, I would state that for equal carbon content a steel containing, say, 3 to 5 per cent. nickel should not be heated to as high temperatures prior to either oil tempering, water tempering, or annealing as a steel of the same carbon content but containing no nickel.

The advantage of nickel steel for purposes where in service high physical qualities are demanded lies in the fact that the

higher proportional elastic limit can be obtained by the presence of nickel, and, furthermore, any danger of brittleness is avoided from the fact that the desirable physical properties can be obtained in a nickel steel without as high a carbon content as is necessaary to meet the same high physical qualities when adopting a simple carbon steel. Mr. Colby.

G. H. CLAMER.—Has Mr. Colby ever made any determination of the wear of journals of nickel steel as compared with carbon steel? Mr. Clamer.

MR. COLBY.—I have never seen the results of any trials of nickel steel as a journal-bearing material. I have already quoted the comparative test of nickel-steel axles and carbon-steel axles which show that the nickel-steel has, if anything, a lower coefficient of friction than carbon steel, and this fact, in connection with its acknowledged increased resistance to abrasion referred to by our President, Dr. Dudley, would indicate that nickel steel might prove a better material than carbon steel for the purpose suggested by Mr. Clamer. Mr. Colby.

MR. CLAMER.—I should think that would be the case. I remember some years ago our President, Dr. Dudley, read a paper on the wear of materials, in which he showed that inasmuch as wear was the tearing off of small particles from the worn body, the finer the granular structure of material the slower would be the rate of wear; and inasmuch as this nickel steel has a finer grain than ordinary carbon steel, I should think the rate of wear would be slower. Mr. Clamer.

J. C. KINKEAD.—The American Locomotive Company is duplicating orders for engines with driving-wheel axles, crank-pins and piston-rods of nickel steel; some of the roads have been using them for a great many years and with great success. I knew of one mill where they formerly had to replace the vertical rolls every two and a half to three months, and by the substitution of nickel steel they now last two and a half to three years. Mr. Kinkead.

MR. COLBY (by letter).—In summarizing the discussion which this paper has created, I want to call particular attention to the important point brought out by Mr. McLeod, namely, that the large steel-makers of this country, who make certain parts of their own machinery, have adopted nickel steel for the vital parts of their large machinery, whenever they have Mr. Colby.

Mr. Colby. had trouble with the frequent breakages of these parts, heretofore made of ordinary steel. I know of instances where our large steel manufacturers have used nickel steel with very gratifying results for the following purposes: forged piston-rods for steam hammers; cast V-shaped die blocks for steam hammers; cast cylinders for large hydraulic presses; gearing, spindles and boxes for heavy blooming mills; rolls for cogging mills, beam and plate mills, and rail mills; crank-pins for heavy engines and a large number of similar minor engine parts where frequent breakages, due to severe strains in service, have caused annoying and expensive stoppages in mill operations.

In the course of the interesting remarks made by our President, Dr. Dudley, he testifies to the marked increase in the resistance to abrasion of nickel-steel rails after a five years' trial. Orders have been placed during this year for 11,000 tons of nickel-steel rails, principally for laying on curves where the rails at present in use have needed very frequent renewal. Some eight of the leading American railroads are included in these trial orders, and the results will doubtless, later on, lead to the general adoption of nickel-steel rails on sharp curves, particularly as, in addition to their increased resistance to abrasion, the higher elastic limit of the nickel steel increases the value of the rail as a girder. The statement made by Mr. McLeod in reference to the relative cost of nickel-steel rails and carbon-steel rails may be summarized in tabular form as follows:

COMPARATIVE COST OF NICKEL-STEEL RAILS AND CARBON-STEEL RAILS.

	Nickel-steel rails.	Carbon-steel rails.
Cost of the tonnage of rails necessary to maintain a certain curve for a given period . . .	$56.00 (1 ton at $56.00)	$84.00 (3 tons at $28.00 per ton)
One ton of rails made of 3½% nickel steel contains 78.4 lbs. of nickel, which at 20 cts. per lb. equals a credit of	$15.68	$0.00
Credit for scrap rails	16.00 (1 ton)	48.00 (3 tons)
Total credit	$31.68	$48.00
Gross cost (as above)	$56.00	$84.00
Total credit (as above)	31.68	48.00
Net cost	$24.32	$36.00

The comparison shows that the nickel-steel rail, notwithstanding its increased initial cost, is ultimately the more econom-

ical, even without taking into account the saving in the cost of the maintenance of the track due to the less frequent relaying of the nickel-steel rails on the curves, which, as is well known, is considerably greater than the cost of relaying straight track. It is probably safe to state that the cost of relaying rails on curves is at least $2 per ton. Mr. Colby.

Mr. McLeod touches on a vital point in the successful substitution of nickel steel for carbon steel in his statement that in many cases a nickel steel too low in carbon has been selected to replace the simple carbon steel which has failed in service for some particular purpose. Dr. Dudley also refers to this point in his remarks where he states that for some purposes for which nickel steel has been tried a little higher carbon in the nickel steel would probably have been an advantage.

While it is true that a certain tensile strength can be obtained in a 3½ per cent. nickel steel of a considerably lower carbon content than necessary in a simple carbon steel, yet it should be borne in mind that nickel in itself does not harden the steel, but rather has a toughening action, and that in cases where the service demands a certain hardness and stiffness as well as strength, care should be taken to select a nickel steel of sufficiently high carbon content, as otherwise the full advantage of the increased resistance of the nickel steel to alternating stresses is not obtained.

Dr. Dudley refers to a few cases coming under his personal observation where nickel steel has not given the long service expected. In my opinion these occasional failures could be traced, either to the trial of a nickel steel too low in carbon for the purpose intended, or more often to the nickel steel having received an improper heat treatment prior to its delivery to the consumer. The critical points of nickel steel are lower than carbon steel of the same carbon content. This necessitates a change in the temperatures used in hardening or annealing nickel-steel forgings or castings from those used in the heat treatment of simple carbon steel. There is no mystery connected with the proper heat treatment of nickel steel. Nickel steel is more sensitive to improper heat treatment than carbon steel, but it is perfectly practicable to give nickel steel the proper heat treatment so as to put it into the best condition for service; and it only requires the exercise of a fair amount of intelligence to avoid the production of a coarse,

crystalline structure in the finished product, which is, of course, as detrimental a condition in carbon steel as in nickel steel.

As stated in the preface of this paper, the advantages obtained by alloying nickel with iron and steel have been long known and have been acknowledged by many investigators. The few cases in which the adoption of nickel steel for a certain purpose has not met expectations is really a proof of the necessity of a better acquaintance with the grade of nickel steel best suited for a given purpose; and with the simple precautions necessary to take in its manufacture and heat treatment, rather than a proof that this natural alloy of two metals, so closely allied in their properties as nickel and iron, does not fulfil the claims made for it by those who are best acquainted with its valuable properties.

Briefly, the addition of nickel to steel increases the proportional elastic limit, adds to the ductility of steel, and increases its resistance to compression and to shocks. Engineers are seeking to-day for a material having this desirable combination of physical properties.

ALTERNATE STRESSES IN BRIDGE MEMBERS.

By Gustav Lindenthal.

The rules prevailing for the dimensioning of bridge members subject to alternate tension and compression have been discussed by me on previous occasions. (See *Transactions of the Canadian Society of Civil Engineers*, 1889, vol. iii. page 89; also *Transactions of the American Society of Civil Engineers*, 1896, vol. xxxvi. page 444.)

I expressed on these occasions my dissent from the rules which have been adopted for the bridge specifications of some of the principal railroads in this country, taking the ground that they are based on erroneous conclusions and a wrong interpretation of such tests as had been made on this point.

I have recently gone over the subject again in connection with the designs for two of the large East River Bridges at New York City. One is the cantilever design for the Blackwell's Island Bridge, and the other is the suspension bridge design for the so-called Manhattan Bridge. In both designs occur members exposed to reversal of stress from tension to compression or *vice versa*. Both bridges are among the heaviest ever built, the dead load being nearly twice the extreme live load, and the alternating stresses are here slowly cumulative, and the maxima can occur only on the rarest occasions.

The question may be said to have been scientifically investigated first by A. Woehler in his famous experiments on the resistance of metals to repeated and alternate stresses, undertaken in 1859 and continued by him until 1870. The results which he obtained changed the then prevailing notions on the resistance of metals very materially.

Experiments on similar lines had been made before, but they were few in number, and did not produce the overwhelming effect of the millions of repetitions of the Woehler experiments. The every-day experience of engineers with the movable parts of engines and machines, car axles and shaft cranks, all exposed to

sudden variations of strain, had long ago led them to empirical rules which indirectly provided for lower unit stresses than were thought sufficient for steady loads. The effect of moving loads on bridges had also been recognized before, especially by American engineers in their railroad bridge specifications.

Launhardt, who succeeded Woehler in his work, repeated many of the latter's experiments and verified them. And by a mathematical reasoning he deduced what is known as the "Launhardt Formula," which he also applied to dead-load and live load stresses, such as usually occur in bridges. It makes no provision, however, for reversals of stresses from compression to tension and *vice versa*, such as occur in stiff diagonals near the center of simple spans, or in chords of continuous trusses near the points of contraflexure, or in stiffening trusses of suspension bridges, etc.

Later, Prof. P. J. Weyrauch, in his book on the *Strength and Determination of the Dimensions of Structures of Iron and Steel*, 1877, deduced in an analogous manner a formula for alternately reversing stresses, which is generally used together with the Launhardt formula. But, while basing his formula for alternate stresses on Woehler's experiments, Weyrauch was quite aware of the lack of completeness in these experiments. He says: "In his (Woehler's) experiments the stress was repeated very rapidly; the strains, however, require a certain time in order to reach their full intensity. What influence now has the rapidity of the repetition, what influence the rapidity of the increase of stress, and what the duration of the individual stresses?" It appears that Weyrauch knew the weak point of his formula, as applied to bridge work.

Failures of iron and steel structures were not infrequent at that time, and the Woehler experiments were taken up as a ready excuse for many failures of structures, which were probably due to faulty detail and poor workmanship.

The general introduction into American practice of the Launhardt-Weyrauch formulæ dates with the Pennsylvania Railroad Specifications and Mr. J. M. Wilson's paper before the American Society C. E. on "Specifications for the Strength of Iron Bridges," in 1885, after giving the Launhardt-Weyrauch formulæ as:

$$a = u \left\{ 1 + \frac{\text{Min. B.}}{2 \text{ Max. B.}} \right\} \text{for repeated stress of one kind,}$$

$$a = u \left\{ 1 - \frac{\text{Max. B.}}{2 \text{ Max. B.}} \right\} \text{for alternate reversal of stress.}$$

Mr. Wilson finds that these formulæ do not provide for impact, as they really do not, and following the lead of Mr. Wm. Cain in his little book *Maximum Stresses in Framed Buildings*, 1878, he adopts:

$$a = u \left\{ 1 + \frac{\text{Min. B.}}{\text{Max. B.}} \right\}$$

$$a = u \left\{ 1 - \frac{\text{Max. B.}}{2 \text{ Max. B.}} \right\} \text{respectively.}$$

It should be noted that thus an extra provision, above that of Launhardt's, was made to account for "impact, vibration, etc., such as is caused by live load." In the interesting discussion of this paper much adverse and weighty criticism was expressed by experienced bridge engineers. Mr. Theo. Cooper, for instance, expressed the opinion, that "at the best they simply represent the breaking strains; whereas, it is now generally accepted that for permanently safe structures we must have regard solely to the permanent elastic condition of every member."

G. Bouscaren, in his discussion, stated: "No experiments have been made for alternate tension, except where the opposite stresses are equal. The formula for alternate stresses of opposite signs is deduced entirely by a process of reasoning from the results obtained in this particular case. The influence of rapidity of repetition, rapidity of increase of stress and duration of individual stress have not been investigated."

Mr. C. C. Schneider, in his contribution, remarked that "I have of later years used a similar formula for the same object. Not that I believe in the correctness of the formulæ of Launhardt and Weyrauch as deducted from Woehler's experiments, but as a convenient empirical method of increasing the sections for impact in proportion of the ratio of dead to live load."

Mr. Schneider's remark probably expresses the best position

taken by American engineers in reference to the Launhardt-Weyrauch formula. They all recognize the value of the Woehler experiments, and the important bearing of the laws deduced from them, as formulated by Woehler, but the majority of them do not believe in the applicability of these formulæ to bridge construction. The discussion at a later date of H. B. Seaman's paper, "The Launhardt Formula on Railroad Bridge Specifications," before the American Society C. E., indicated clearly a general opinion that fatigue formulæ were irrational, and should not be used in the proportioning of bridge members. The reason that some engineers still use that formula in one or the other form is not because the designer wishes to make provision for repeated stresses, but because he wants to provide for impact and vibrations due to the live load; and, as we have seen in the case of Mr. J. Wilson's specifications, the impact effect is included in addition to the repeated stress effect.

There is evidently much reason for doubting the applicability of Woehler's conclusions (which were mostly based on rapid, repeated applications of load to rotating axles and spindles) to such bridge members which, barring impact, receive their stress more or less gradually, and at intervals of time which are many thousand times those of the experiments. There is still less reason for believing in the correctness of the Launhardt-Weyrauch formulæ for bridge members subject to comparatively slow reversal of stresses. While counter-stresses in railroad bridges from rapidly moving trains are subject to rapid reversion of stresses, this does not apply in the same degree to chords in continuous trusses, or in arches, or cantilevers.

In this connection it is interesting to note the views of European engineers and investigators:

In discussing Woehler's experiments, in his work on the *Application of Iron and Steel for Structures*, the French engineer Considère, who is one of the most careful and experienced experimenters, raises the following objections to the Woehler experiments:

First, the laws formulated by Woehler are based on a comparison of results obtained from different pieces, which were not of the same quality. The tests were made on wrought axles which, as is well known, do not show much uniformity and give

different resistances and elongations at different points. "For comparative experiments axles are badly chosen. The results of a series of tests cannot, therefore, be rigidly compared." The difference in strength of a lot of axles varies 15 to 20 per cent. The values obtained for alternate stresses as well as for repeated stresses for the limits of ultimate strength, when compared, cannot furnish perfectly well-based conclusions.

Secondly, the short duration of the application of stress. The duration of the application of the greatest stress was $\frac{1}{12}$ of a second, or 720 times per minute, which makes the results inapplicable to structures whose members receive their stress more slowly and at much longer intervals.

Thirdly, a wrong application of the bending formula, as based on the theory of flexure, which holds true enough within the elastic limit only, and which is considerably in error after passing the limit of proportionality.

Thus, reviewing Woehler's results, Considère accepts the Woehler law as to alternate stresses in the following form:

"For the durability of metal, the case of alternately reversed stresses of equal amount is the most unfavorable. The ultimate limit for repeated alternate stresses is considerably below the elastic limit, and is probably nearly one-half of this value, if the duration of the reversal of maxima stresses is about $\frac{1}{12}$ of a second, as it was the case for Woehler's experiments."

The views of German engineers on that question were subsequently much influenced by the great series of experiments conducted by Bauschinger at the Munich Laboratory. They proved, in the words of Winkler, that "repeated stresses have a detrimental influence only above the elastic limit, and alternate strains up to near the elastic limit."

Dr. A. Foeppel, the successor of Bauschinger, in his work on the *Theory of Resistance* (vol. iii. of *Technische Mechanik*) says: "The oscillatory resistance of equal values on each side is usually somewhat lower than the greatest resistance of the metal to repeated stresses from 0 to maximum in one direction." But according to the most reliable experiments by Bauschinger, this difference is much less than it was assumed before, based on the Woehler results. The following table gives Bauschinger's values:

No.	Ultimate Strength.	Repeated Stresses.	Alternate Stresses.	Percentage of Alternate in Values of Repeated Stresses.
1. Wrought iron	49,500	28,450	25,170	88.5 per cent.
2. Ingot iron	62,000	34,140	28,160	82.5 per cent.
3. Material not specified ..	57,600	31,290	28,160	90.0 per cent.
4. " " " ..	57,180	34,130	32,140	94.0 per cent.
5. Thomas steel	87,050	42,670	42,670	100.0 per cent.
6. Rail steel..............	84,480	39,820	39,820	100.0 per cent.
7. Boiler plate, ingot iron..	57,600	34,130	27,000	79.0 per cent.
8. Material not specified ..	47,650	31,290	22,750	73.0 per cent.

I have added the column of percentages to show that an allowance of 25 per cent. over the stress allowed of stress of one variety would be fully sufficient for rapid applications of load, for rapid reversals and for very short durations of rest. It will be observed that the lowest values in the column for alternate stresses, in the above table, are very near the elastic limit of the respective materials. It is reasonable to assume, therefore, until further data be established, that for bridge members where the conditions of traffic guarantee a certain rest between reversals, no extra allowance of cross-section is required for stresses well within the elastic limit.

This I believe will become, if it is not already, the established practice among experienced bridge engineers, for the proportioning of the sections of bridge members subject to comparatively slow reversal of stress well within the elastic limits of the metal.

ON THE CONSTITUTION OF CAST IRON.*

By William Campbell.

When the evidence of microscopic examination is taken into consideration, there can be no doubt that we have to deal with a single series as we pass from pure iron, through steel, to cast iron.

Their relations can well be demonstrated by Bakhuis-Roozeboom's diagram,† which shows that above 1100° C. the series form a simple set of alloys. In other words, their freezing-point curve belongs to Group I. of Le Chatelier's classification and consists of two inclined branches, intersecting at the eutectic point. Up to 2 per cent. of carbon the series are solid solutions called martensite. About this point the graphite-martensite eutectic or mother-liquor appears, and as the carbon contents increase the eutectic increases and the martensite decreases, until at 4.3 per cent. of carbon the whole mass consists of the eutectic of alternate laminæ of graphite and martensite. On further increasing the carbon we have graphite separating from the mother-liquor because the latter is supersaturated with graphite. The above holds good for pure, slowly cooled carbon-iron alloys.

When the temperature falls below 1100° C. great changes in the solid take place. The martensite becomes unstable and itself acts like a simple liquid alloy. Thus below about 660° C. we find that the martensite has rearranged itself and now consists of either pearlite alone, pearlite + ferrite or pearlite + cementite, according as the original solid solution of martensite contained 0.8 per cent., less than 0.8 per cent., or more than 0.8 per cent. of carbon.

The saturation-point of the solid solution martensite is about 2 per cent. carbon, hence above 2 per cent. carbon the slowly

* Discussion of a paper under a like title, by Prof. Henry M. Howe, in *Proceedings of the American Society for Testing Materials*, Vol. II. pp. 246–275.

† Zeitschrift f. phys. Chem., vol. xxxiv.; Metallographist, 1900, pp. 293–300.

cooled alloys consist of graphite in a matrix of about 20 cementite and 80 pearlite.

If the cooling were sufficiently slow to produce a state of equilibrium, an abrupt transformation would occur at 1000° C., the martensite and the graphite combining to form cementite. But the reaction takes so long that it does not occur to any appreciable extent in ordinary slow cooling. Hence, in slowly cooled pure iron-carbon alloys we pass from pure iron or ferrite, through alloys containing increasing amounts of pearlite, till at 0.8 per cent. C. we have the whole mass made up of pearlite. With increase of carbon, cementite appears and the alloys consist of increasing amounts of cementite in decreasing amounts of pearlite. At about 2 per cent. C. the cementite reaches its maximum and above that point we have graphite making its appearance, and the alloys consist of graphite, cementite, and pearlite.

On the other hand, if the elements silicon, manganese, phosphorus, and sulphur, etc., are present, they will play a very important part. In pig irons, etc., they are often present in the matrix in great quantities, and we are no longer dealing with a series of binary alloys of iron and carbon, but with that of multiple alloys of iron, carbon, silicon, etc. When cooling has been relatively fast, the various changes may be in part eliminated, or may even be suppressed altogether.

Quenching an alloy between 0 and about 2 per cent. C. tends to prevent the separation of the ferrite or cementite, whichever is in excess, and prevents the change of martensite into pearlite completely.

Above 2 per cent. C. quick cooling or chilling from liquid state tends to prevent the separation or crystallization of the martensite and prevents the formation of the graphite-martensite eutectic entirely. The mother-liquor solidifies in the form of a eutectic certainty, but of cementite and martensite, and we get a white cast iron.

As before, the elements silicon, manganese, etc., when present to any great extent, will tend to modify or even prevent the changes which occur in a pure carbon-iron alloy. The following photographs illustrate several of the varieties of cast iron.

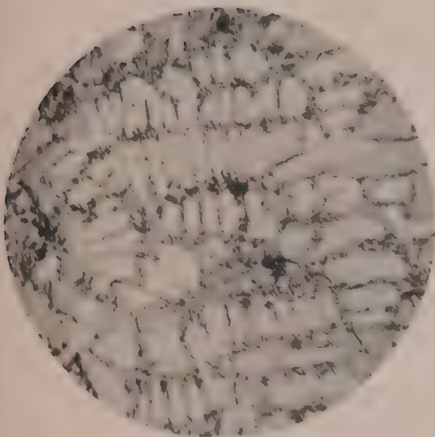


FIG. 1.—Gray Cast Iron. × 30.

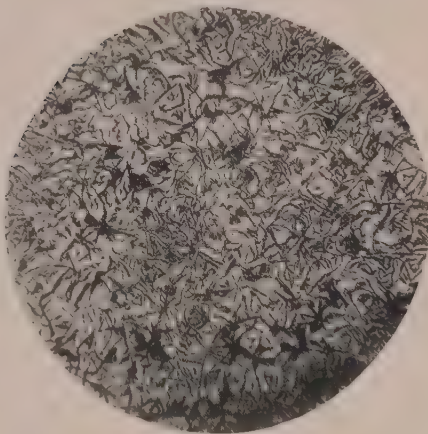


FIG. 2.—Gray Cast Iron. × 30.

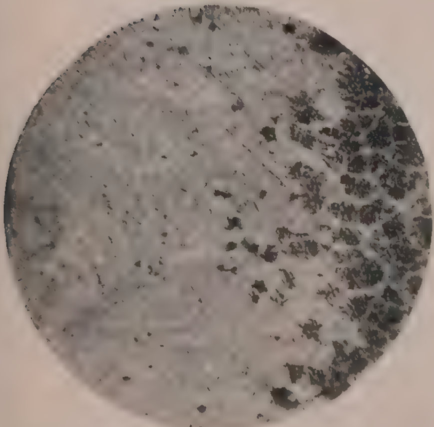


FIG. 3.—Cast Iron. Chilled white. × 30.

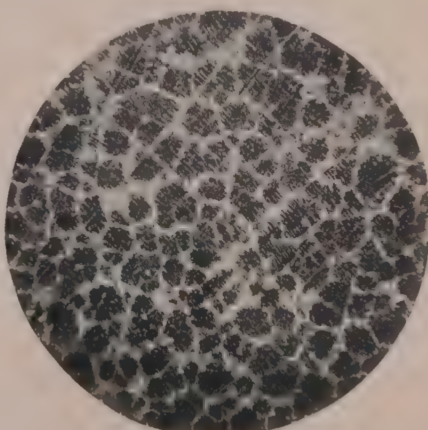


FIG. 4.—Cast Iron. Mottled. × 30.

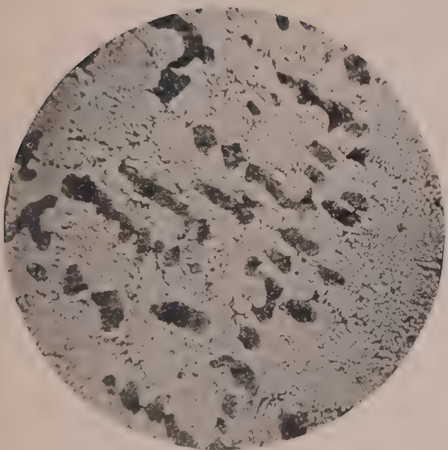


FIG. 5.—Washed Metal. × 30.

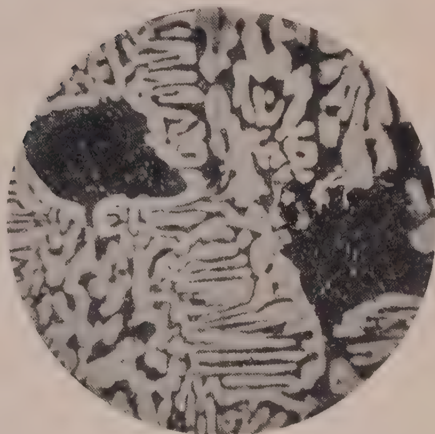


FIG. 6.—Washed Metal. × 100.

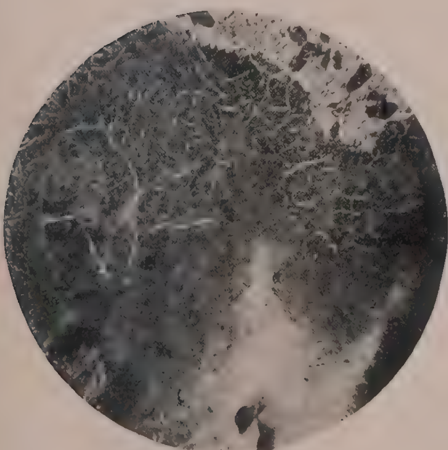


FIG. 7. Washed Metal, reheated and quenched at about 670° C. × 30.

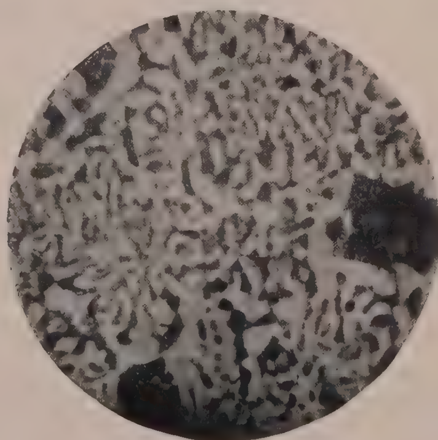


FIG. 8.—Upper part of Fig. 7. × 100.

Fig. 1 contains 2.9 per cent. C., 1.44 per cent. Si., 0.23 per cent. Mn. × 30.

The specimen has been lightly etched with nitric acid, and shows dendritic crystals set in a laminated ground-mass or eutectic of graphite and the same material as the dendrites. At first these might be mistaken for ferrite, but with deeper etching and a higher power they are seen to be composed of true pearlite with an excess of cementite. In other words, they are dendrites of martensite which have rearranged themselves into cementite and pearlite.

When the metal cooled down from the liquid state, dendrites of martensite crystallized out, enriching the mother-liquid in carbon. At a lower temperature, say about 1150° C., the ground-mass solidified as the eutectic of martensite and graphite. As the temperature fell the martensite became saturated with cementite, which began to separate out at about 1000° C., whilst finally at about 660° C. the residual martensite, containing probably about 0.8 per cent. C., changed to pearlite.

In Fig. 2 we have a cast iron containing from 4 to 4.5 per cent. C. × 30 diameters. Its composition approaches that of the graphite-martensite eutectic. Hence, on cooling the whole mass solidified as alternate laminæ of martensite and graphite, while, as before, at a lower temperature the martensite rearranged itself into cementite and pearlite, which are quite distinct under a higher power, as in Fig. 12.

In Figs. 3 and 4 we have a cast iron which has been chilled, × 30 diameters. Fig. 3 shows the outer layer and consists of white cast iron having a structure similar to that of Fig. 5.

Fig. 4 shows the center of the piece and has a cell-like appearance. The borders of the cells are composed of white cast iron, the centers of gray, whilst the whole gives us the mottled structure.

In Fig. 5 we have a section of washed metal containing 3.5 per cent. C. × 30 diameters.

Here we have the coarser form of white cast iron, showing dark dendrites set in a eutectic. No graphite is present.

In Fig. 6 we have the same, × 100 diameters, and here we see that the dendrites are composite. What has happened is as follows: On cooling from the liquid state, dendrites of martensite

have crystallized out, enriching the mother-liquid with respect to carbon. Owing to rapid cooling, and probably some other cause also, the mother-liquor passed the point of solidification of the graphite-martensite eutectic before freezing. When solidification did occur a eutectic of cementite and martensite formed, probably because the metal had reached the temperature at which the reaction of martensite + graphite = cementite could take place. In other words, the metal had reached a point where graphite and martensite were no longer in stable equilibrium.

As before, when the temperature fell the martensite became supersaturated with cementite, which commenced to separate out, and under normal conditions this would continue until the martensite had a composition of 0.8 to 0.9 per cent. C. at about 660° C., when it would be transformed into pearlite. In Fig. 6 the excess of cementite can be seen as white dots in the larger dark patches, which under a higher power are seen to consist of pearlite and unsegregated pearlite or sorbite.

By means of a simple experiment the whole series of carbon-iron alloys can be obtained in one section. A piece of washed metal was taken and heated to about 1050° C., and then allowed to cool slowly in the furnace; another piece was heated to same temperature and quenched in cold water, whilst a third was allowed to cool at about 670° C. and quenched. Each specimen was cut very obliquely, in order to give the maximum surface to the outside portion; then each was polished and etched. The outside is found to consist of iron oxide, next comes pure iron, then carbonized iron, till we reach 3.5 per cent. C., at the depth of about $\frac{1}{8}$ inch.

Fig. 7 shows the specimen quenched at about 670° C., × 30 diameters.

Here, starting at the bottom of the photograph, we see an irregular dark patch of iron oxide surrounded by an irregular mass of ferrite. Beyond the borders of the light ferrite we have the dark mass of martensite, which has almost wholly rearranged itself into pearlite. Had the quenching taken place well above the recalescence point, this would have been true martensite. Passing on, we see the cementite coming in, whilst finally at the top of the figure we have the original washed metal. Thus in the

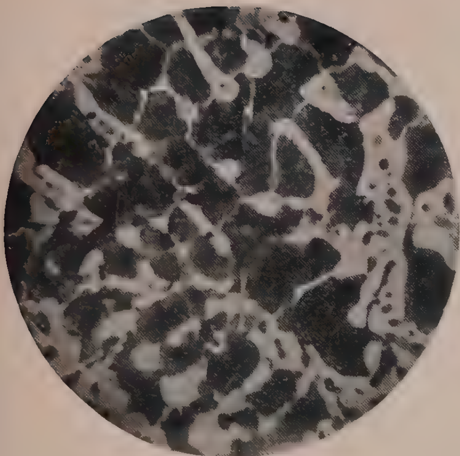


FIG. 9.—Area around Fig. 8. × 100.

FIG. 10.—Area around Fig. 9. × 100.

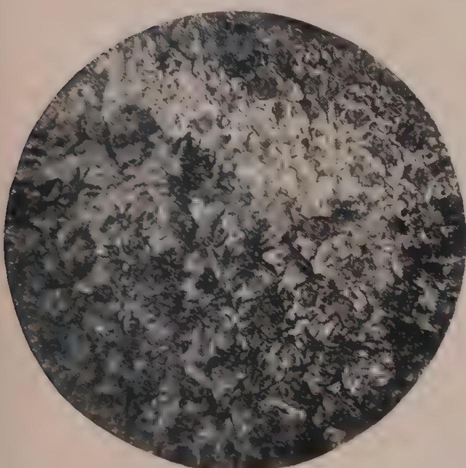


FIG. 11.—Washed Metal, reheated and slowly cooled. × 30.

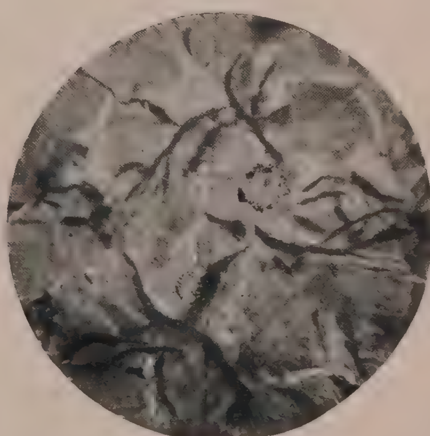


FIG. 12.—Lower part of Fig. 11. × 100.

FIG. 13.—Washed Metal, reheated and quenched at about 1050° C. × 30.

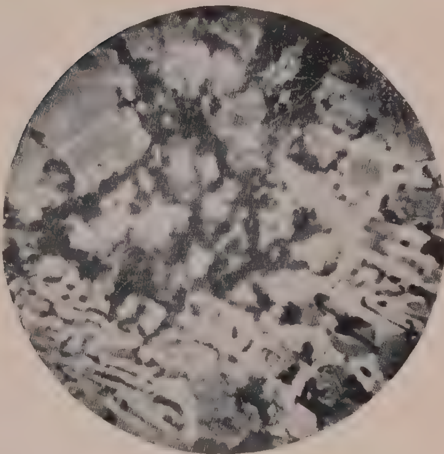


FIG. 14.—Washed Metal, reheated and quenched at about 1050° C. × 100.

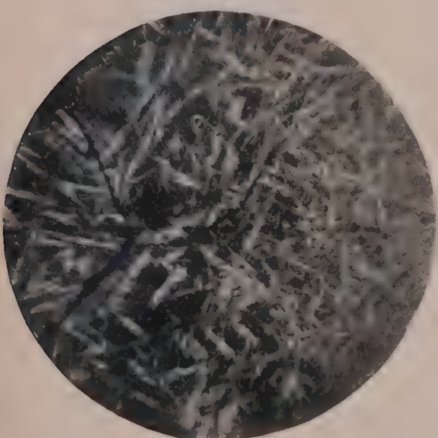


FIG. 15.—Washed Metal, reheated and quenched at about 1050° C. × 100.

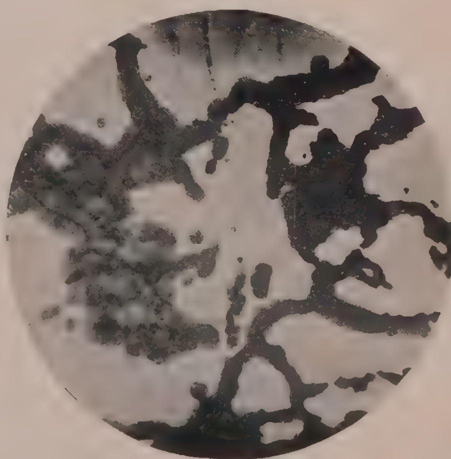


FIG. 16.—Washed Metal, reheated and quenched at about 1050° C. × 30.

one figure we pass from pure iron to iron containing 3.5 per cent. C., or white cast iron. There is no break in the structure of the series.

Fig. 8 is a view from the upper part of Fig. 7, or of the white cast iron, × 100. It is very similar to Fig. 6, showing that little or no change has taken place.

Fig. 9 is a view from near the edge of the white cast-iron area of Fig. 7, × 100. The relative amount of cementite has greatly decreased, due to decarburization, and here we have the connecting link between white cast iron and a high carbon steel.

Fig. 10, × 100, shows a further decrease in carbon and closely resembles a steel containing some 1.4 per cent. C. The view is taken from the cementite-pearlite area, and we see the characteristic veins and bands of cementite set in a matrix of pearlite. Owing to the fact that the specimen was quenched at about the lower transition point, Ar_1, it is probable that part of the matrix consists of unsegregated pearlite or sorbite.

Passing toward the outside of the specimen, decarburization causes the disappearance of the free cementite, when the whole is pearlite, then the introduction of patches and veins of ferrite, giving a view similar to Fig. 10. As the ferrite increases the pearlite decreases, till finally it disappears altogether, and we have nothing but ferrite with a covering of oxide at the surface of the specimen.

Considering next the specimen which was allowed to cool slowly within the furnace.

Fig. 11, × 30, vertical illumination, shows a section similar to Fig. 7, but not covering such a wide area. At the top of the figure we see a patch of the original washed metal or white cast iron. Passing down, we see a sudden change, due to the disappearance of most of the cementite and the appearance of much graphite. This shows that this specimen had reached the temperature at which the cementite had been split up into martensite and graphite.

Fig. 12, × 100, shows a view from the graphitic area. The large irregular plates of graphite are seen set in a matrix consisting of cementite and pearlite. This matrix was formed by the

rearrangement of the martensite as the temperature fell. The whole shows a gray cast iron.

As we pass to the outside of the specimen the graphite soon disappears, as in the base of Fig. 11. Then we have the whole series, the same as in Fig. 7, except that the pearlite is much clearer and coarser, due to the very slow cooling. Again, we find there is no break in the series as we pass from the outside, consisting of pure ferrite, through pearlite with about 0.8 per cent. C., through the high-carbon series consisting of increasing cementite in pearlite, until graphite makes its appearance, and we have gray cast iron.

The most interesting specimen was that which was quenched from the maximum temperature of heating. Here we find the whole series of structures due to hardening by quenching.

Fig. 13, × 30, shows a section through the series, as in Fig. 7. At the top we see the remains of the original washed metal. Forming a series of rings around it are the structures of hardened steels containing decreasing amounts of carbon. First we see a black irregular material which proceeds downward as a vein, finally forming the boundaries to some of the martensite crystals. It is the black constituent of Figs. 14 and 15. Next comes a light material which gradually passes into the dark ground-mass, with white chevrons, remarkably like Osmond's specimen of austenite and martensite. This finally passes into regular martensite as we approach the edge of the figure. In the specimen the boundary between the martensite and the ferrite could not be distinguished.

In Fig. 14, × 100 diameters, several constituents can be seen. The white hard cementine stands out in relief in the lower half of the figure. In many places the cementite is enclosed in austenite, through which long needles are seen. These needles, Le Chatelier has identified with cementite. The dark material is probably sorbite due to the decomposition of the austenite.

Fig. 15, × 100, shows a section nearer the outside of the specimen, therefore containing less carbon, from left to right being in direction of decreasing carbon. The black material may be sorbite, for it is continuous with that of Fig. 14, and forms the boundaries between the crystals or grains which are composed of white chevrons and bands in a darker ground. The white portions

are martensite and the colored portion austenite. On the extreme right-hand side we see the normal variety of martensite of medium carbon steels.

Fig. 16, × 30 diameters, shows a section near the surface of another piece of washed metal which was heated and quenched at the maximum temperature as before. There are, apparently, two constituents, one light, resembling austenite, the other dark and similar in appearance to that transition form of high-carbon steels called sorbite by Le Chatelier, though Stead and Osmond call a similar body troostite. Under a higher power the dark material is seen to be traversed by needles of cementite exactly similar to those seen in Fig. 14, which in many places are seen crossing the sorbite as well as the austenite.*

With regard to the light constituent, there is some doubt as to its being austenite. On deep etching, darker bands are seen in places, as is shown in the top patch in the figure. Le Chatelier has called something very similar "pseudocrystalline sorbite," which often occurs on the surface of quenched high-carbon steel. At all events, the white material is not homogeneous throughout, though this may very probably be due to the partial separation of martensite. It is a fact that austenite is seldom found alone, but is almost always accompanied by martensite or cementite.

From the above it is seen that steel and cast iron form one continuous series, without any sudden break in their structures. The dividing line between them at about 2 per cent. carbon coincides with the appearance of the graphite-martensite eutectic in the case of gray cast iron and of the cementite-martensite eutectic in the case of white irons, and no more stress ought to be laid upon this division than that at 0.8 to 0.9 per cent. C., separating steels containing ferrite from those containing cementite, in the free state.

* Mr. Stead kindly examined photographs 14 and 16 and immediately identified the dark constituents as troostite.

DISCUSSION.

Mr. Field. H. E. Field.—I should like to say a word in regard to Professor Howe's paper "On the Constitution of Cast Iron." Professor Howe holds that cast iron is steel with graphite intermixed, and to substantiate this claim he assumes that cast iron with 1.20 per cent. combined carbon has the maximum tensile strength and that this strength decreases as you go either way from this amount. He assumes that graphitic carbon reduces this strength in a certain ratio to the amount present. This looks very well on paper, but the cast iron metallurgist can but notice several flaws in the reasoning. Professor Howe states that the matrix of a cast iron with 1.20 per cent. combined carbon will stand 120,000 pounds tensile strength per square inch and then goes on to show why cast iron with this amount of combined carbon has not this strength. While Professor Howe does not give a complete analysis of his iron, from our knowledge of cast iron we should assume that in the cast-iron sample the sulphur would run at least 0.1 of 1 per cent. and silicon at least 1.40 per cent.; the phosphorus at least 0.40 per cent. Are there any records of a steel with 1.20 per cent. combined carbon, 1.40 per cent. silicon, 0.1 per cent. sulphur, and 0.4 per cent. phosphorus developing a strength of 120,000 pounds? I think not. Here, then, the first assumption is incorrect. If, therefore, Professor Howe has succeeded in reasoning from an incorrect assumption to correct results the reasoning must be wrong.

In actual experience with many hundred tests, I have found that the maximum tensile strength of cast iron occurs in irons much lower than 1.20 per cent. combined carbon. In fact, one-half that amount, or 0.6 per cent., would come nearer to giving the maximum tensile strength of cast iron.

As much as the cast iron metallurgist would like to adopt this theory for cast-iron practice, practical results show it to be

impossible. The percentage of combined carbon in a casting varies from the outside to the inside. The action of the iron in cooling and the latent heat given out in the separation of the graphite produce a matrix which varies greatly from steel of the same combined carbon. That this matrix is uneven in the distribution of its combined carbon is suggested, I believe, by Behrens, who shows that the iron around each crystal of graphite is lower in combined carbon than the rest of the matrix. In the introduction to the paper Professor Howe suggests that we use the knowledge already gained in our study of steel as a vantage ground from which to study cast iron. He takes issue with those who hold that the knowledge gained from steel is of but little value when used in connection with cast iron and claims that these writers have advanced no proof to support this contention. We would suggest that the burden of proof hardly lies with the latter but with Professor Howe and those who would apply their knowledge of steel to cast iron. We would also suggest that the chief reason why investigations into the metallurgy of cast iron has progressed so slowly has been that steel methods have been applied to cast iron and found wanting. In steel 0.2 per cent. silicon, 0.1 per cent. phosphorus, 0.05 per cent. sulphur, and 1.5 per cent. carbon are about the maximum amounts of these impurities dealt with. In cast iron we have to consider silicon up to 4 per cent., sulphur up to 0.15 per cent., phosphorus up to 1.5 per cent., and carbon up to 4 per cent. When one appreciates the great effect of even a small amount of these elements on steel he will appreciate the large reactions that the cast-iron metallurgist is forced to control. Mr. Field.

Professor Howe wonders why the act of conferring a distinct name cast iron upon the iron-carbon compounds rich in carbon has operated to debar investigations along this line, meaning by this, I take it, along the line of steel. This is easily answered—cast iron is valuable for two reasons: first, on account of its fluidity, and second, on account of its low shrinkage. It is these two properties which make it so valuable as a cast product and have led to its being called cast iron. Have these two properties, low shrinkage and fluidity, any close relation to the properties of steel which we are urged to use as a model? Carbon in steel has been

Mr. Field. studied in regard to its effect on hardness, strength, and ductility. Carbon in cast iron must be studied with relation to the fluidity and shrinkage of that product. Silicon in steel has been studied with such small percentages present that the knowledge gained is of no value in connection with cast iron. In steel, silicon appears to act in a similar way to carbon, only in a modified degree. In cast iron silicon is valuable because it adds softness, fluidity, and low shrinkage to the iron. Phosphorus, which is debarred from steel and kept as low as possible, becomes a very important item in cast iron for many grades of work.

The cast iron metallurgists appreciate the need of further study in the metallurgy of cast iron and welcome the efforts of their steel friends in their behalf; but it must be remembered that if cast iron is to be placed on a par with steel in our investigations we shall have to begin at the bottom, as we did with steel, and work up the metallurgy of cast iron, as our steel friends did the metallurgy of steel.

Mr. Clamer. G. H. CLAMER.—I should like to ask why ideas as to the saturation-point of carbon have apparently changed within the past few years? If I remember rightly, Professor Howe two years ago placed it at 0.80 per cent., and now he seems to place it at 1.20 per cent.

Mr. Sauveur. ALBERT SAUVEUR. I think the saturation-point has always been considered to lie in the vicinity of 0.80 per cent. Mr. Clamer confuses the saturation-point with the point of maximum strength. Professor Howe argues that a steel containing 1.20 per cent. carbon has the maximum strength, but he does not mean that it is a strength test. This corresponds to the saturation-point, for he knows that there is an excess of cementite present.

Replying to Mr. Field's remarks, the strength of cast iron does not depend exclusively upon the amount of combined carbon. It also depends to a very great extent upon the graphitic carbon present. It is qui e possible for a 0.50 per cent. combined carbon cast iron to be stronger than a sample with 1 per cent. combined carbon if the former contains much less graphitic carbon than the latter. Graphitic carbon, of course, decreases the strength, and we could not draw any conclusions unless we knew that both cast irons had exactly the same proportion of graphite. I think Pro-

fessor Howe's idea was that the cast iron of greater tenacity would of course have a matrix of greater tenacity, and therefore, from the fact that steel a little oversaturated has the greatest strength, he argues that the matrix of the strongest iron should be slightly oversaturated. Mr. Sauveur

MACHINE-CAST SANDLESS PIG IRON IN RELATION TO THE STANDARDIZING OF PIG IRON FOR FOUNDRY PURPOSES.

By Edgar S. Cook.

The blast furnaces now in operation represent all sorts and conditions, as referred to shapes, sizes, and equipment. The tendency for some years past, however, has been to eliminate the smaller stacks of an earlier generation, so that fewer furnaces are producing a vastly increased product, as compared with the statistics of only ten years ago.

The modern blast furnace, with its daily product of 400 to 600 tons of pig iron, has been of gradual growth, and become a possibility only through the accumulated experiences of intelligent and educated managers, capable of applying the teachings of science, and at the same time thoroughly trained by a severe apprenticeship in the practical every-day routine of actual working. More intelligent management, as compared with the "rule-of-thumb" method, rendered evident the necessity of stronger equipment and larger furnaces, to insure economies, and the latter in turn called for improved mechanical appliances to handle in a limited time the large tonnages of raw materials necessary to keep the furnaces in continuous operation.

The casting machine for handling the iron product followed as a natural consequence, more, however, to overcome the labor problem of moving the iron from the cast house than for any other reason. The machine-cast iron gives promise of solving, or at least helping to solve, the difficulties that have always attended the sampling of pig iron, especially the foundry grades. The casting machine may prove an unexpected benefit in removing "a bone of contention" between consumer and maker, and enable the foundry to receive a more reliably uniform iron—pig for pig—than is possible under sand-bed conditions.

From the conditions surrounding the production of pig iron, as well as the constitution of cast iron itself, variations in composition are unavoidable. So many causes come in to effect the

working of the blast furnace, all of which show on the iron, to say nothing of the variations in the raw materials used, the only wonder is that the product of the blast furnace does not show wider ranges or fluctuations, and that the composition is under the control that has been found possible, by careful management.

Notwithstanding, however, the most careful attention on the part of the manager, one cast will differ from another in composition, and individual beds of the same cast will differ. These facts were only established by frequent and continued analyses. Within only comparatively recent years, the furnaces have been able, with the help of well-equipped laboratories, to select different casts, to suit the specifications of customers, or their assumed requirements, based upon experience, in the absence of specified analysis. Fortunately, all grades and varieties of pig iron have their uses. Investigations that will add to the store of information and guide in the proper use and application of the data obtained by laborious research, should be welcomed and encouraged by all users, as well as by all makers of pig iron.

Indications all point to the substitution of analysis for the old-time method of grading by fracture. Commencing with the larger users, and the makers of specialties, requiring more positive information as to the composition than was afforded by the fracture, the use of pig iron guided by analysis has spread with much greater rapidity to all classes of foundry work than the most sanguine expected.

Grading by fracture, as guided by experience with any particular brand of iron, has some points in its favor, else it would have been supplanted earlier. The fact that for so many years castings of multitudinous forms, and for an endless variety of uses, were made in a fairly satisfactory manner by skilful guessing as to mixtures, only goes to demonstrate that for many classes of work there is a very considerable range in composition allowable, without injuriously affecting the castings. With accurate knowledge as to requirements, and more positive information as to the composition of pig iron, there will doubtless be a smaller percentage of loss of defective castings. The castings themselves will be better adapted for the purpose designed, and the causes of defective work can be more definitely located.

It might just as well be borne in mind, however, that working by analysis will not prove a "panacea" for all the ills to which foundry practice is subject. It will occur to every practical man that there are many causes entering into the success or failure of foundry practice, other than the composition of the pig iron placed at the mouth of the cupola.

There are limitations also to the ability of blast furnaces to furnish the raw pig, within too narrow limits, as pertaining to any particular set of specifications, without unduly enhancing the cost. In the long run the consumer must pay the cost and risks of manufacture, plus a fair profit on the capital invested—otherwise the supply will not equal the demand. There are special irons that must be of certain composition, and must not vary, except within very narrow limits. The manufacture of these demands special ores and special fuels, as well as most careful scrutiny as to the uniformity. The ores and fuels, etc., suited are not in abundant supply, and therefore command high prices comparatively. The unavoidable "misfits" made by the furnace, and sold at less than cost, enhances the average cost of manufacture, for all of which the consumer must ultimately pay.

Blast furnaces could be run with much more comfort to the manager, and with much better average result in every way, were it possible to obtain absolutely uniform raw material—ores, fuel, and limestone. It would also be a great gain if the atmospheric air driven into the tuyeres always contained the same weight of oxygen per cubic foot of air and the same weight of moisture. If all the furnaces operating to-day demanded ores absolutely uniform in composition, that is, the product of any one mine, to run always the same in percentage of iron and gangue, and that the coke should not vary in sulphur, phosphorus, ash, and fixed carbon, the greater portion of the furnaces would be obliged to discontinue operations, and the cost of pig iron would rise to prohibitory figures.

Since chemistry has unfolded the secrets of nature's storehouses of raw material, the uniform ore deposit of coal and of limestone is about as scarce as the perfectly developed man or woman. The furnaces are obliged to take ores, etc., as they find them, and by judicious mixing, based upon an *approximate* knowl-

edge of their contents, endeavor to produce as uniform a product as possible.

This product is the raw material of the foundry, rolling mill, steel works, etc. It is a wise precaution, therefore, in substituting the new system of grading "by analysis" for that of "by fracture," not to draw the lines any closer, nor make the conditions any more severe than is absolutely necessary to meet the requirements of any particular class of manufacture.

I have seen certain crude specifications for pig iron, probably formulated by a young chemist fresh from the technical college, but without any metallurgical training, so rigid and exacting with regard to carbon, silicon, sulphur, phosphorus, manganese, etc., that probably not one cast in a thousand from any one furnace would meet all the conditions imposed.

Reference has been made to the variable composition of pig iron, as referred to sand cast pig, cast in the usual way. Different portions of the same pig will show varying percentages of silicon and sulphur. Different pigs of the same bed will vary one from another, and different beds of the same cast will frequently show wide variations. It is not worth while to here attempt an explanation of the causes, but merely accept the fact as an unavoidable feature of blast furnace conditions, as existing at most of the plants engaged in the merchant business.

In this connection I cannot do better than quote the remarks of Dr. R. W. Raymond, Secretary American Institute of Mining Engineers, in a discussion upon the "Control of Silicon in Pig Iron."*

"The blast furnace is noted as perhaps at once the rudest and the most sensitive of the means employed in manufacturing on a large scale. In proportion to its rudeness and sensitiveness it has always called for exceptional skill in management. By skill I mean here the acquired aptitude of actual practice, including the recognition of symptoms, without the perfect knowledge of their causes. The requirement of skill in this sense has been greatly diminished by the work of chemist and engineers during the last few years. Many of the subtle difficulties and traditional remedies of the blast-furnace practice of twenty years ago are practically obsolete in the art of to-day (February, 1892), with its rapid running, high pressures and temperatures, immense daily products and adequate machinery. But the hampering condition still remains, that these great furnaces,

* Transactions Am. Inst. Min. Engs., vol. xxi., February, 1892.

devouring hundreds of tons of raw material, and producing hundreds of tons of pig iron and slag daily, are required to preserve a certain chemical composition of product. This requirement is often inconsistent with the use of the cheapest ores, the maximum economy of fuel, and the maximum product of iron. In other words, if our blast furnace managers were ordered to produce the largest practicable quantity of pig iron, no matter of what grade or quality, at the smallest cost of ore, flux, fuel, labor, and repairs, the art would be not only simplified, but revolutionized.

"Now this is what has happened in other arts, as the result of scientific improvement. The production of the cruder material has been immensely cheapened, by reducing the element of skill, removing to a great extent the complicated quality, and leaving to subsequent processes, in which science, rather than skill, plays the chiefest part, the final work of perfection and adaptation.

"The barbaric method (as illustrated, for instance, in the Japanese manufacture of steel) consists in the infinite expenditure, according to received tradition, of material, time, and labor, the rejection of the greater part of the product, and the selection of that part which by happy accident has acquired extraordinary excellence.

"The half-civilized method substitutes more and more skill for luck, and science for skill, yet still waits to see what the product will be, and grades it without reference to what it is intended to be.

"The scientific method makes what it started to make. To do this requires to know and to govern the conditions of manufacture, including the exact composition of materials. If this knowledge and control cannot be easily maintained in the first step of manufacture, or if their exercise interferes with the economical operation of that stage on a large scale, the scientific method employs that part of its process as a means of simplifying the conditions for future determination and control."

The blast furnace may be said to be in the "half-civilized" stage, having preceded our foundry friends in emerging from the "barbaric" stage by nearly a score of years. The foundry is really most interested in knowing the exact composition of its raw material—pig iron. This is more important than having it rigidly conform to any particular set of specifications, defining the limits of silicon, sulphur, etc.

Knowing the composition of his raw material, pig iron, it remains for the foundry superintendent to employ the scientific method, and make such a mixture of various brands or irons of varying composition, if unable to obtain one iron to meet all the requirements, in order to produce the result he started to make. The sandless pig, made in the casting machine, gives promise of attaining the desirable uniformity more effectively than can ever

be reasonably expected from sand-cast pig. In the direct process from blast furnace to the bessemer converter and steel ingot, the mixer was found indispensable to insure uniform products and a minimum percentage of defective ingots.

The correct sampling of sand-cast pig is troublesome and expensive. This is especially true of the foundry grades. In order to obtain a fairly representative sample, numerous pigs must be taken and drilled with care. Even then different samplings of the same lot of iron will show frequently widely varying results as to silicon and sulphur, notwithstanding that the same method of analysis may be used. This brings about misunderstandings quite as difficult to adjust as the disagreements with respect to the "fracture" any particular grade should show.

I do not refer to differences that are brought about for commercial reasons, as affecting the price, where judgment is warped by money considerations. I have in mind several experiences of our own, illustrating the difficulty of arriving at the composition of sand-cast pig, when the question of price did not enter into the matter at all, as no particular guarantees had been made. The purchaser required reasonably accurate information to guide him in using the iron, and we co-operated with him in sampling and making analyses, the results being compared. All of the samples selected by us were made by drilling about one dozen pigs to represent each lot of fifty tons.

Purchaser's Sampling and Analysis.		W. I. & S. Co.'s Sampling and Analysis.	
Silicon.	Sulphur.	Silicon.	Sulphur.
1.90	trace	0.964	0.045
1.23	0.04	0.926	0.045
0.85	0.09	0.855	0.050
1.71	0.035	0.880	0.040
1.08	0.040	0.910	0.060
1.03	0.06	1.010	0.080
1.04	0.05	1.08	0.050
1.31	0.04	1.19	0.04
1.50	0.03	1.09	0.06
0.62	0.05	0.74	0.04
0.87	0.03	0.80	0.04
1.21	0.04	0.92	0.07
1.04	0.05	1.08	0.05

The marked discrepancies in silicon were found to be due to particles of sand getting into samples through lack of care in handling, while drilling the sand-coated pigs in the machine shop of the purchaser. The iron sold was all of the gray forge grade.

This experience led us to adopt the method of sampling iron liquid, as it ran from the furnace, which plan was in use by the Western furnaces connected with steel works. It has been found more reliable, as fairly representing iron as it will be used in quantity, than the drilling of several pigs.

At times certain casts run remarkably uniform as to silicon and sulphur, the differences existing between the different beds not being more than can be accounted for in laboratory work, but this is the exception rather than the rule. Phosphorus is generally evenly distributed. Segregation does not seem to affect it, and there is seldom any difficulty in determining the contents. The following will illustrate the variation of sand-cast iron, one pig being selected from the middle of every alternate bed:

Beds.	Open Gray Forge A.		No. 2 Strong B.		Soft Fdy. C.		D.	
	Silicon.	Sulphur.	Silicon.	Sulphur.	Silicon.	Sulphur.	Silicon.	Sulphur.
2.....	1.481	0.068	1.669	0.013	2.52	0.011	2.52	0.014
4.....	1.434	0.066	1.575	0.009	2.60	0.015	2.56	0.013
6.....	1.468	0.074	1.599	0.009	2.66	0.013	2.58	0.013
8.....	1.481	0.066	1.599	0.003	2.80	0.013	2.53	0.012
10.....	1.458	0.056	1.622	0.009	2.92	0.013	2.55	0.012
12.....	1.411	0.060	1.575	0.011	3.01	0.011	2.56	0.013
14.....	1.292	0.066	1.528	0.011	2.92	0.011	2.48	0.013
16.....	1.198	0.056	1.528	0.006	2.04	0.014	2.84	0.013
18.....	1.222	0.055	1.411	0.011	....	.....	....	.....
20.....	1.222	0.048	1.363	0.008	....	.....	....	.....
	Cast Analysis. Liquid Samples.		Cast Analysis. Liquid Samples.		Cast Analysis. Liquid Samples.		Cast Analysis. Liquid Samples.	
	1.363	0.054	1.599	0.012	2.60	0.011	2.50	0.013
	.....	.....	.....	.....	2.23	0.013	2.88	0.015

Cast A—The silicon varies between 1.481 and 1.222, and the sulphur varies between 0.074 and 0.048.

Cast B—The silicon varies between 1.669 and 1.363, while the sulphur happens to be exceptionally low.

Cast C—Shows a wide variation in silicon, 3.01 to 2.04, while the sulphur is very low and constant.

Cast D—Represents a uniform cast, both in silicon and sulphur.

All of the casts were taken at random, sampled, and analyzed. Another series might be more variable in silicon and sulphur, depending upon furnace conditions.

EXAMPLES FROM DIFFERENT PORTIONS OF THE SAME CAST OF SAND PIG.

Grade.	First Sample.		Second Sample.	
	Silicon.	Sulphur.	Silicon.	Sulphur.
No. 2X.	2.23	0.017	2.45	0.015
"	3.29	0.014	2.30	0.091
"	2.16	0.022	1.46	0.018
"	2.15	0.036	2.40	0.027
"	3.24	0.035	2.16	0.060
"	3.20	0.026	3.32	0.017
"	3.21	0.051	3.17	0.036
No. 2	1.62	0.075	2.58	0.033
"	1.88	0.035	2.66	0.013
No. 3	1.25	0.035	0.89	0.050

SAND IRON.

Liquid Samples. Silicon.	Cast Analysis. Sulphur.
2.20	0.021
2.85	0.017

NINETEEN BEDS.

	Silicon.	Sulphur.
Pig from 1st bed	1.99	0.026 / 0.022
" " 3d "	2.17	0.022
" " 5th "	2.29	0.024
" " 7th "	2.46	0.024
" " 9th "	2.57	0.027
" " 11th "	2.60	0.023
" " 13th "	2.66	0.022
" " 15th "	2.85	0.020
" " 17th "	2.36	0.019
" " 19th "	1.80	0.021 / 0.024

This cast shows considerable variation in silicon, while the sulphur is uniform.

Where the iron represented by one analysis ends and the other begins it is a difficult matter to determine. Occasionally physical indications serve as a guide to the experienced grader.

These illustrations show the difficulties besetting the accurate or scientific determination of the composition of sand-cast pig, even when all parties interested are actuated by the best of intentions. When the situation is complicated by mercenary considerations, it can be easily surmised that "grading by analysis" may not be the great boon expected in removing all friction.

It is an improvement upon "grading by fracture," and certainly a safer guide as to the use of all pig iron. It is fortunate, however, that for most classes of foundry work the variations in carefully selected foundry irons are not fatal, due to the range in composition of castings, that practice has proven to be permissible.

In 1892, Dr. R. W. Raymond said: "Even if all pig iron should come to be cast in chills, which would be a very good thing, I have no doubt the grain would still be found legible as an inscription of quality, though the handwriting would be finer and the language a new one."

This we have found to be especially true of machine-cast sandless iron. The process of handling the molten iron from the furnace to the pig, as shipped, changes the physical appearance of the fractured surface so radically that entire dependence must be placed upon the analysis, until such time as the "new language" has been learned.

I have been agreeably surprised at the aptitude shown by foundry consumers generally, and especially those not working by technical rules, in comprehending the novel appearance of machine-cast sandless iron—so different from the standards previously considered essential. We have fully appreciated the confidence of the trade, and willingness to tread in new paths. To justify this confidence, we aim to exercise every possible precaution that our analyses fairly represent the iron. Careful investigations indicate that if the chemical composition is as desired for any particular work, the physical appearance can be entirely neglected without any risk whatever. What the "mixer" is for the Bessemer steel

works, the 20-ton ladle cars are for sandless foundry iron. The molten iron, running into the ladle from the furnace, becomes thoroughly mixed, and the pouring from ladle in a smaller stream into the moving metallic molds should bring about a more complete mixing, so that the composition of individual pigs, taken at random from the first pouring of ladle and last portion, ought to show insignificant variations, and compare closely with one another.

The analyses of machine-cast sandless foundry iron would indicate that the expectations are being realized.

	Silicon.	Sulphur.
Cast E, one ladle:		
Pig from first pouring	3.01	0.015
Pig from middle pouring	3.00	0.009
Pig from last pouring	3.10	0.010
Average liquid sample	3.05	0.010
Cast F, two ladles:		
First ladle, pig from first half	1.97	0.022
First ladle, pig from second half	1.97	0.022
Average liquid sample	1.82	0.019
Second ladle, pig from first half	2.08	0.020
Second ladle, pig from second half	2.04	0.020
Average liquid sample	2.22	0.015
Cast G, two ladles:		
First ladle, pig from first half	2.30	0.011
First ladle, pig from second half	2.29	0.011
Average liquid sample	2.30	0.025
Second ladle, pig from first half	2.43	0.010
Second ladle, pig from second half	2.41	0.012
Average liquid sample	2.51	0.031
Cast H, two ladles:		
First ladle, pig from first half	2.07	0.021
First ladle, pig from second half	1.97	0.021
Average liquid sample	1.72	0.023
Second ladle, pig from first half	2.10	0.027
Second ladle, pig from second half	2.10	0.025
Average liquid sample	2.50	0.014
Cast K, two ladles:		
First ladle, pig from first half	2.17	0.014
First ladle, pig from second half	2.18	0.017
Average liquid sample	1.96	0.013
Second ladle, pig from first half	2.34	0.021
Second ladle, pig from second half	2.39	0.018
Average liquid sample	2.40	0.013

	Silicon.	Sulphur.
Cast L, two ladles:		
First ladle, pig from first half	2.17	0.049
First ladle, pig from second half	2.18	0.047
Average liquid sample	2.24	0.041
Second ladle, pig from first half	2.09	0.042
Second ladle, pig from second half	2.12	0.042
Average liquid sample	2.19	0.031
Cast M, two ladles:		
First ladle, pig from first half	2.11	0.018
First ladle, pig from second half	2.08	0.016
Average liquid sample	2.04	0.021
Second ladle, pig from first half	2.32	0.017
Second ladle, pig from second half	2.11	0.016
Average liquid sample	2.35	0.021
Cast N, two ladles:		
First ladle, pig from first half	1.99	0.027
First ladle, pig from second half	1.94	0.026
Average liquid sample	1.77	0.031
Second ladle, pig from first half	2.12	0.028
Second ladle, pig from second half	2.14	0.030
Average liquid sample	2.22	0.028
Cast O, two ladles:		
First ladle, pig from first half	2.17	0.014
First ladle, pig from second half	2.15	0.013
Average liquid sample	2.20	0.014
Second ladle, pig from first half	2.21	0.014
Second ladle, pig from second half	2.16	0.013
Averave liquid sample	2.30	0.020
Cast P, two ladles:		
First ladle, pig from first half	2.39	0.013
First ladle, pig from second half	2.17	0.013
Average liquid sample	2.15	0.009
Second ladle, pig from first half	2.43	0.014
Second ladle, pig from second half	2.47	0.015
Average liquid sample	2.98	0.012
Cast R, two ladles:		
First ladle, pig from first half	2.49	0.012
First ladle, pig from second half	2.50	0.010
Average liquid sample	2.50	0.013
Second ladle, pig from first half	2.50	0.012
Second ladle, pig from second half	2.49	0.015
Average liquid sample	2.28	0.013

It will be observed that as a rule there is a close correspondence in the analyses of pigs taken haphazard from different parts of the same ladle and of the liquid sample of the ladle. Also that the average of these analyses for the entire cast do not differ materially from the average of the analyses of the liquid samples representing the same cast. The exceptions are less than might be expected, and may be regarded in the light of "exceptions proving the rule."

Cast P was evidently a variable cast, somewhat similar to sand-cast C. If the cast P had been run into sand beds some of the beds would have been filled with 2.15 per cent. silicon iron, and others with 2.98 per cent. silicon, and intervening beds with silicons between the two extremes. By "mixing" in the ladles this wide variation is in a great measure corrected, the iron of each ladle being reasonably uniform.

Referring to cast R, the pig samples of the first ladle and the liquid sample are practically identical. The pig samples of the second ladle compare with one another and with those of the first ladle, but differ from the liquid sample supposed to represent the contents of the second ladle. In this instance the man taking liquid sample evidently forgot himself, or for some reason neglected to "dip" his sample from the running stream until the end of the cast, or when the ladle was nearly full. The quantity of 2.28 per cent. silicon was too small to affect the average of the ladle, as shown by the analyses of the pigs.

The liquid samples are taken by a laborer without the exercise of any judgment whatever, except to obey general directions that several samples shall be taken to represent each ladle, viz.: from the first, middle, and last run of iron of each ladle. Some better plan may be developed, but it is probably as trustworthy as any method that can be devised to suit blast-furnace conditions.

With but few exceptions, machine-cast sandless foundry iron has met with unqualified approval. When anything goes wrong with any particular heat in the foundry it is only human nature that the responsibility should be placed upon the new brand of iron used in cupola mixture. If this happens to be sandless iron differing greatly in physical appearance from recognized standards of long standing, it is only natural that the sandless iron

should be held responsible. Several instances of this kind have occurred.

The investigations following have not only served to remove censure and prejudice, but at the same time to demonstrate the unusual uniformity of sandless iron, pig for pig.

Customers have been requested to select and forward pieces representing, from their views, the worst-looking pieces physically to be found in the car. By the "worst-looking" I refer to pigs that show a porous or spongy structure, in consequence of the molten iron boiling when poured into a damp or cold mould. This boiling destroys the grain, and the appearance is such as to warrant misgivings on the part of the inexperienced user. So far as our investigations have gone, and based also upon the experience of those using the iron, the solid pigs, whether close or open in fracture, and the porous pigs from one ladle, show the same composition, and compare closely with the average liquid sampling of ladles. When remelted in cupola the results are the same.

The following analyses are given to illustrate:

	Silicon.	Sulphur.
Ladle analysis	1.86	0.028
Solid pig from car	2.00	0.027
Porous pig from car	2.10	0.028
Ladle analysis	2.03	0.021
Porous pig	2.05	0.025
Cast average }	{ 2.25	0.025
First ladle }	{ 2.35	0.017
Second ladle	2.12	0.021
One pig from car (solid fracture)	2.32	0.014
One pig from car (porous fracture)	2.11	0.016
Borings from individual pigs, at random from car:		
Sample 1	2.10	0.023
" 2	2.17	0.016
" 3	2.09	0.016
" 4	2.10	0.012
" 5	2.13	0.015
" 6	2.10	0.013

The data so far collected go to show that the casting machine is the agent by which practical uniformity, with a reasonable allowance for the human fallibility of employés, can be obtained in the composition of any particular cast, one pig compared with

another, and will insure greater uniformity in the raw material of the foundry. It remains for the furnace to select the casts that fall within the specifications of any particular customer, as to silicon, sulphur, etc. If the specifications are not unnecessarily rigid, with allowances for the conditions affecting blast-furnace practice and the necessarily imperfect control over the alloys entering into its product, foundrymen will find in machine-cast sandless iron a useful assistant in helping to solve some of their problems.

The physical appearance of machine-cast sandless iron is influenced by several conditions, which have no effect upon the quality, as determined by chemical composition.

In a paper entitled "Blast Furnace Compared with Cupola Practice," etc., attention was called to the many causes affecting the fracture, etc., of sand-cast pig. Similar causes operate to influence the physical appearance of sandless pig. To enumerate: The casting temperature from tapping hole of blast furnace, together with rapid or slow running into ladle car; the pouring temperature from ladle into molds; the temperature of molds, whether cold, warm, or hot; the generation of gas from water of hydration in the lime coating of molds, causing agitation of the molten iron and more or less boiling.

The casting machine is formed of two parallel strands of molds. The speed or rate of movement can be regulated within certain limits. Usually the speed is such that any pair of molds are fifteen to twenty minutes in moving from the pouring end to the discharge end—distant 90 feet. In this time the liquid iron poured into the mold sets or freezes, forming a skin or shell. This shell is strong enough to carry weight of pig when discharged upon plates of conveyor. The interior, however, is in a liquid or semiliquid condition.

When the molds are thoroughly heated, from having been filled the second and third time, without opportunity to cool, the shell forming exterior of pig is not strong enough to carry the weight. It cracks when dropped on conveyor, and "bleeds." The pig will thus become hollow. This necessitates a temporary stoppage of the casting machine to allow time for the setting of the metal. In the highly heated condition the pigs are carried

by conveyor into a bath of water. The pigs are submerged for eight to ten minutes, and rapid cooling sets up internal strains so violent that upon emerging from the water-bath many of the pigs break into halves or quarters, etc., depending in a great measure upon the silicon contents. Sometimes, with low-silicon pig—below 0.50 per cent.—the strains are so violent that large pieces are thrown out of the conveyor, jumping three or four feet, with a report like the discharge of a pistol. I presume the same effect would be noticed in iron containing high percentage of silicon, say 4 per cent. or over. Irons containing 1 to 2 per cent. silicon show but small percentage of broken pigs. With silicon over 2 per cent. the breakage increases in proportion to the increase in silicon contents.

While this effect may make the iron rather inconvenient to "stock" in customers' yards, at the same time it has the counter advantage of permitting better distribution in the cupola. For small cupolas this should be a distinct benefit.

The advantages of sandless iron accrue chiefly to the foundry. The benefit to the furnace is found solely in relieving the management from the labor troubles incident to securing men to break hot iron in the pig beds and remove from beds in the limited time necessary. As an economical proposition, our experience of a year or more would show that there is no saving of expense, but rather the reverse. The cost of labor and of maintenance of the casting machine is in excess of the human machine. In addition, the yield of ore mixture in iron is less when the shipments are of sandless iron, as compared with sand-cast pig, thus showing that notwithstanding the usual allowance for sand, the customer receives more pounds of iron per ton of sandless than of sand-cast pig. This fact, together with greater ease of melting in cupola (the sand covering being more infusible than iron) and the greater uniformity of casting-machine sandless iron, will explain why it has met with such general favor.

Referring to the infusibility of the sand-coating of pig iron, I am informed by a very observant manager of a puddle mill that he has frequently noticed in the hearth of a puddle furnace that the iron melts, leaving the empty silicious shell standing in the bath of liquid metal. This is broken down by the workman, and is then liquefied.

My attention has also been called to the fact that similar shells are occasionally found in the debris, upon the dropping of the bottom of a cupola. Several years ago a foundry superintendent, who had noticed the silicious coating when the bottom of his cupola was dropped, asked me if we could not furnish pig with all metallic surfaces. He argued that as the iron melted, and the sand coating at the same temperature did not, that the latter was an injury, in the way of requiring a larger quantity of fuel than would otherwise have been found necessary. He was agreeably surprised when told that in the course of a few months we would be able to supply him with pig iron entirely free from sand.

All sand is not of the same fusibility. Quartz is very infusible, while another variety of sand may contain silica, alumina, and lime in such proportions that it may fuse at the same temperature as cast iron. Pig irons therefore cast in sand of differing grades or composition would be expected to show different results in this respect.

Our experience with respect to sandless pig has been quite unique. It was to be expected that the pioneers, inaugurating such a revolution in the preconceived notions of foundry iron, would meet with more or less opposition and encounter difficulties in introducing machine-cast iron, calculated to discourage. This has not been our experience, and the fact speaks volumes for the intelligent appreciation and progressive spirit of the foundrymen much beyond the expectations of many of their associates, and certainly more than the innovators had any reason to expect.

Almost without exception those who have given casting-machine sandless iron a fair trial request continued supplies in preference to sand-cast iron.

Distinction is to be made between machine cast sandless and the sandless pig made in chill molds. While the latter shares with the former all the advantages due to absence of sand coating, it is lacking in the more important element of uniformity, pig for pig. The beds of chill molds simply replace the beds of sand, and are filled in the same way— one bed after another as the metal is run direct from the furnace, without the intervention of a "mixer" in the shape of a large ladle car, and the further intimate mixture consequent upon pouring from ladle into molds.

DISCUSSION.

Mr. Vannier. C. H. VANNIER: What is the weight of a cast?

Mr. Cook. EDGAR S. COOK: About 30 to 35 tons. At present we are running our small furnace on foundry iron.

Mr. Vannier. MR. VANNIER: How do you pile the iron from the different casts?

Mr. Cook. MR. COOK: For the last several years we have not been piling; we have been shipping. It is very unusual for us to pile; but when we do pile it is done according to the differences in the analyses, allowing a variation in silicon of about 0.25 to 0.5 per cent., and in sulphur of about 0.01 to 0.02 per cent.; one pile will thus contain iron running between 2 and 2.5 per cent. in silicon, etc.

Mr. Vannier. MR. VANNIER: In this sandless pig iron you cannot detect any distinction in composition from the appearance.

Mr. Cook. MR. COOK: Yes, you can, when you learn the signs. The foundrymen can learn these by handling sandless pig just as well as in the case of sand pig.

Mr. Vannier. MR. VANNIER: Suppose you should have an iron containing 2 per cent. of silicon and 0.03 per cent. of sulphur and another iron containing 2.5 per cent. of silicon and 0.05 per cent. of sulphur, can you distinguish the difference?

Mr. Cook. MR. COOK. No, not with such small differences.

Mr. Vannier. MR. VANNIER: You could pile the iron of those two different classes in a carload and the consumer could not distinguish them from each other?

Mr. Cook. MR. COOK: No, they would be intimately mixed, and we would give the average analysis. The carload of iron would be graded at 2.25 silicon under these circumstances.

Mr. Vannier. MR. VANNIER: The uniformity of the iron as received by the consumer depends on the care used at the furnace in shipping these different casts separately.

Mr. Cook. MR. COOK: It is very largely a question of personal equation.

Mr. Vannier: With sand pig the fracture will give the consumer more or less accurate information as to whether the iron is high or low in silicon or sulphur; whereas with the sandless iron he has no means of knowing this. He must depend entirely upon the accuracy used in the piling and shipping from the furnace. Mr. Vannier.

Mr. Cook: I think he has to do so very largely also in the case of sand pig. I do not think there is very much difference in that particular between sand and sandless pig. Mr. Cook.

Mr. Vannier: Of course, you can distinguish between No. 4 and No. 1 iron very readily in their fracture. Mr. Vannier.

Mr. Cook: Yes; the difference in fracture is well marked. There is no difficulty whatever in distinguishing the grades of sandless pig by the appearance when the variations are considered, after the "new language," as Dr. Raymond has called it, is learned. There are really better opportunities for learning to determine the composition of sandless iron by sight than in the case of sand iron. Mr. Cook.

Mr. Vannier: We use a good deal of sandless iron, and generally speaking, it has been very uniform; but we have received shipments where, in the same carload, some of the pigs have shown a gray fracture and some have shown a white, chilled fracture. On analyzing the different samples, we have found, of course, as might have been expected, very wide variations in the chemical composition. Mr. Vannier.

Mr. Cook: You certainly would under those circumstances, which would indicate carelessness at the furnace in shipping. Mr. Cook.

THE PHYSICAL PROPERTIES OF MALLEABLE CASTINGS, AS INFLUENCED BY THE PROCESS OF MANUFACTURE.

By Richard G. Moldenke.

As the matter of specifications for cast iron and finished castings is attracting considerable interest, it may perhaps be well to call attention to the necessity for a special clause in the one on "malleable cast iron" limiting the processes allowable in its manufacture. The necessity for this action is the result of recent developments along the line of heat treatment given the hard castings.

As a general proposition, it has been long known that the hard castings may be either annealed a long time at the regulation temperature, or only a short time if the temperature be considerably higher. The results, while apparently the same, in that the combined carbon of the castings becomes the "temper carbon" characteristic of a good piece of "malleable," are in reality not so reliable as might be expected in the case of the higher heat. There are several processes now in use which aim to reduce the period of anneal, to cheapen the cost, and to make quicker deliveries. Unfortunately, however, whether from an insufficient knowledge of the science of heat treatment or from lack of uniformity of material, the castings produced are not always good "malleable," and lead to much loss and annoyance.

Until we know more of the behavior of the iron going into the malleable castings when heated beyond the ordinary annealing temperatures, it would be well to call for a minimum number of hours during which the work to be tested for acceptance has been given the full heat of the ovens. For light work this might be placed at sixty hours, and for ordinary or heavy material at seventy two. When the makers of malleable castings, who anneal their work a few hundred degrees higher and thus shorten the period, can prove to the buyer that they can do this successfully every time, this clause relating to length of time under full heat can be modified or done away with. So far, however, these varieties

of the malleable casting seem to be sold as steel, and very likely to consumers who cannot tell the difference.

For the benefit of the foundry industry, it is to be hoped that the heat treatment of the malleable casting be thoroughly investigated, and on a commercial scale. Much of value would be learned in this way, and the spasmodic attempts to reduce the cost of annealing by varying the method of carbon conversion be brought down to a scientific basis and subsequent business results.

In addition to the annealing question there must be considered the melting process to be followed. Three methods are now in use here: the cupola, air furnace, and the open-hearth processes. Lately a modification of the Bessemer process is being introduced, but it is too new to be taken into account yet. The crucible process, which undoubtedly gives the best results, is obsolete in this country. Contact with the fuel during melting cannot do otherwise than injure metal so low in silicon as this must be, and hence the cupola process gives the poorer grade of "malleable," the higher annealing temperature required not improving matters either. For important work this class of malleable is always excluded. Where, however, there is no necessity to resist shock, and the factor of safety is amply large, there is no reason why cupola malleable should not be used, and about a half cent or so a pound be saved.

As between the air-furnace product and that of the open-hearth, the latter, when produced properly, is undoubtedly the best, and the industry is gradually working in that direction. The expression "produced properly" is used advisedly, as the mistake of using steel melters for getting out "malleable" heats is made only too often. The consequence is an attempt to get a reaction between the oxygen introduced with the carbon of the bath, with the result that the former remains and poor iron results. The malleable process should not be made a refining process, in spite of the prevalent theories to that effect. The reduction of the total carbon undoubtedly improves the tenacity of the castings, but this is best accomplished by the addition of steel scrap. The temperature of the melt is unfortunately not sufficient, even in the open hearth furnace at the time of pouring, to bring about the carbon oxygen reaction completely, and hence the metal is affected injuriously.

Were it steel, the addition of ferro-manganese would soon mend matters; but unless to remove undue sulphur, this should be kept away from "malleable."

A plentiful application of muscle to get a quick and even melt is what is wanted for malleable work, and hence while it is good to have an open-hearth expert about to preserve the furnaces, he should not run the heats, a muscular "Hungarian" doing much better.

The air-furnace product, though not so good as that of the open-hearth, on account of the longer duration of the melting period, is nevertheless serviceable for the best class of work, and hence no distinction need be made in drawing up specifications. Attention to this difference is only called here to benefit those who may have trouble with their installations. Personal experience with both classes of castings for many years would indicate that the open-hearth material has the advantage over the air-furnace product by about 2000 pounds per square inch in tensile strength, this figure being the average taken from a large number of samples cut from castings of both kinds. As, however, it is undesirable to run the tensile strength too high, say not over 52,000 pounds per square inch or thereabouts, and air-furnace iron can be made to touch this point readily, there is no immediate cause for worry. A moderately strong iron is, in fact, better able to resist shock, and therefore specifications should only give the minimum tensile strength, say 40,000 pounds per square inch. The highest limit obtainable has reached 63,000 pounds.

The near future will doubtless bring out much on the process question in malleable, and indeed a good set of specifications covering the best practice will hasten it on.

CAST IRON.

A Consideration of the Reactions which Make it Valuable.

By Herbert E. Field.

My reason for bringing so general a consideration before a body whose chief attention is devoted to the study of testing lies in the fact that if we are to successfully adopt tests for cast iron we must have a complete knowledge of its composition and reactions. It has been the lack of this knowledge that has led to repeated statements that cast iron was not a reliable product, that its composition was only an imperfect guide to its properties, etc.

Only in the midst of actual experience in melting and using all grades of cast iron, under different conditions and for different kinds of work, do we begin to realize its complex nature and reactions. Under such conditions one is able, in endeavoring to explain the many problems and apparent contradictions which arise, to get an inkling concerning the causes which underly these changes, and to explain many of them. Cast iron has not, to my knowledge, been previously presented in the light in which it will now be considered.

The properties which make cast iron an invaluable product are its low shrinkage and its fluidity, which combine to produce an exactness in outline of mold, together with its adaptability to various kinds of work from the softest casting to the hardest chilled product. We know that carbon, silicon, sulphur, phosphorus, and manganese each has its part in producing the above properties. We are acquainted in a more or less accurate degree with the intensity of the actions of different percentages of these elements. This knowledge is, however, but superficial, and is obtained by observing the effects of certain amounts of these elements on the resultant product. The reasons for these results and the reactions which take place during their accomplishment are what we are now concerned with, and for which we will try and offer an

explanation. A consideration of the reactions which make cast iron valuable will form the subject-matter of my paper.

Cast iron is iron containing various impurities which give it the properties necessary for its application as a cast product. It is distinguished from cast steel by its carbon content. The line where cast steel leaves off and white iron begins is an indeterminate one, and will become more and more so as we become better acquainted with this subject and put our knowledge into practical operation. We are wont to divide cast iron into two regular divisions: white and gray iron. In the former we have the malleable and chilled divisions; in the latter the innumerable different grades of gray iron, each adaptable for a different kind of work. I have said that the per cent. of carbon was the distinguishing line between cast iron and cast steel. I further state that cast iron is cast iron because of its carbon. We must take into account the properties of this exceptional element if we would study cast iron and would understand the varied reactions which take place in its formation. The fact that carbon, of all the elements, will produce these effects upon iron gives us the clew to the various phenomena noted in our study. Let us for a moment consider these properties which make carbon the controlling element in cast iron. We have as yet been unable to melt carbon; the highest temperature of the electric furnace has failed to overcome the attraction between its particles and change it to a liquid. It is this property which makes carbon so prominent a factor in iron and steel. It will be further noted that the temperature to which iron is heated, and the forces exerted by the iron particles during these temperatures, is sufficient to overcome the attraction existing between the carbon particles and to allow them to move freely about with the iron particles in the melted iron; or, inasmuch as we are for the moment considering the properties of carbon, we can reverse this statement and say that the attraction between the particles in the carbon is just such as is overcome by the high temperature of iron, together with the action of the particles of iron at such temperatures. Tin, lead, antimony, and copper have no such effect on carbon. Either their temperatures are too low, or the action of the particles insufficient to bring about the disruption of the carbon. The carbon molecule is considered to have

a large number of atoms, and this fact has its application in its action in cast iron. The specific heat of carbon at high temperature is 0.450, which is, with the possible exception of beryllium, the highest of any known solid element, and this varies as the temperature rises. (The explanation of the bearing of this point will be made later in the paper.) We have then four properties which make carbon the controlling element in cast iron:

First. Great attraction exists between its particles.

Second. This attraction is overcome at just such temperatures and by just such action as is present in cast iron.

Third. The carbon molecule is composed of a large number of atoms.

Fourth. It has a high specific heat, which increases as the temperature rises.

We are told that cast iron is a mixture of steel and fine graphite. If true, it is an interesting fact to know, but it is of little practical value to us in our use of cast iron. It is the reactions which take place in the formation of the product which will prove of value, if we can but understand and control them. A ladle of steel, with graphite mixed in mechanically, would not be much like cast iron. It is the reactions which take place and the manner in which they take place, when this graphite forms, that make cast iron so useful a product. Its first value lies in the fact that it may be cast into molds and retain the form of these molds even though they be thin and intricate. It is valuable then because of its fluidity.

Take a ladle of steel in the molten state; it will set quickly; it will not run thin intricate shapes; it shrinks badly. Let us now mix with it mechanically some graphite, stirring it in well with a rod. Will it remain hot any longer? Will it run a thin casting any better? Will it shrink any less? Not perceptibly. What is it then that makes our cast iron suitable for casting?

Pure iron when melted has none of the properties which would make it suitable for a cast product. Carbon and iron under certain conditions make what is known as cast iron. What are these conditions?

If we bring molten iron at a sufficiently high temperature in contact with incandescent carbon the iron will absorb the carbon

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or will enter into a solution with the carbon. Let me again refer to the strong attraction existing between the carbon particles. This attraction must be broken or weakened to allow this formation of solution by the carbon and iron. When two bodies enter into solution heat is rendered latent. So in our iron-carbon solution there must be heat given up to overcome the attraction existing between the carbon particles. The amount of heat so used up must be considerable, when we consider the great attraction existing between the carbon particles. This heat rendered latent in the solution of the carbon with the iron must be changed into motion of the particles of the carbon.

Pure iron under maximum conditions of temperature is said to absorb about 0.5 per cent. of carbon. The latent heat used up in the solution or dissolution of this carbon, together with another element, which will be considered later, forms the chief factor in reactions which cast iron undergoes in the casting process. Let us assume for the moment iron heated to a sufficiently high temperature and holding 6 per cent. carbon in solution. This iron is allowed to cool slowly; as the temperature decreases some of the carbon particles reunite and give up their motion, which is changed back into heat. In other words, a part of the carbon separates out of solution and in so doing gives up its latent heat of solution and prolongs the cooling of the iron. This continues, and as the temperature decreases more carbon separates out, and more heat is given up and the cooling is prolonged. It is this giving up of latent heat as the carbon separates out of solution which prolongs the fluidity of cast iron and makes it valuable as a cast product. The act of casting iron into molds sets into action the latent power which makes cast iron so useful. We pour cast iron into a mold; the action of the mold upon the iron reduces its temperature; in doing so it reduces its power to hold carbon in solution, and the carbon in separating out gives up the latent heat which prolongs the fluidity just at the instant when this fluidity is most needed. This then accounts for the fluidity.

The second important property of cast iron is its low shrinkage. As iron high in carbon cools from a high temperature while still in the molten state, the carbon separates out and may be seen flying from the top of the metal. This is readily seen in our

casting houses. After casting, however, the outside of the casting soon sets and the carbon can no longer be thrown off as it separates out during further cooling. It is retained in the iron as graphite or free carbon interspersed between the particles of iron. It is this separation of the carbon in the interior of the casting after the outside has set which accounts for the low shrinkage of cast iron as compared with steel. That this shrinkage is proportionately less the higher the carbon content, coincides directly with this assumption.

We have another action of carbon to consider, viz.: its action after the solution of iron and carbon is set, but is still at a very high temperature. It is known that solid iron at a high temperature will absorb carbon from incandescent carbon; that at a high temperature combined carbon will change to temper carbon, as in annealing; that carbon will pass from a piece of high-carbon steel to a low-carbon steel held in contact with it and both heated to a sufficiently high temperature. These facts prove that when iron is in an apparently solid state the carbon particles are free to move about and react.

Saniter's analysis of an iron containing 4.27 per cent. carbon and cooled slowly gave a combined carbon of 1.22 and a graphite of 3.05. This would indicate that the amount of carbon which pure iron normally holds in solution in the solid state is about 1.20.

We have before noted that the greatest amount of carbon which could be held in solution was 6.5 per cent., and this only under maximum conditions of purity and temperature. The saturation point of pure iron for carbon varies between 6.5 and 1.22, according to the temperature, and as an iron saturated for a certain temperature cools below that temperature carbon separates out until when the iron sets it holds approximately 1.20 per cent. carbon in solution. The amount of heat evolved depends upon the temperature and the amount of carbon in an iron-carbon solution when it begins to cool.

We have assumed in this instance that the iron was allowed to cool slowly. If it were cast against a chill and the heat immediately removed all the carbon could be prevented from separating from solution and thus from giving up its latent heat. The fact

that the same iron when chilled and when allowed to cool slowly produces such a different structure, indicates that the latent heat of solution which is held by the quick cooling in the first case and in the latter is allowed to react, is a very strong factor in determining the character of cast iron. We can draw many examples from every-day practice to show the effect of this evolution of heat by saturated iron in cooling. If we allow two irons, one with 4 per cent. carbon and the other with 2 per cent. carbon, both with low silicon, to cool slowly, one will have a gray fracture and the other a white fracture. In the former example the heat evolved by the 4 per cent. less 1.20 per cent., or 2.80 per cent. carbon, in separating from solution so prolongs its cooling as to allow for a separation of graphite. In the latter the 2 per cent. less 1.20 per cent., or 0.8 per cent. carbon, does not evolve sufficient heat to accomplish this. Slow cooling then is absolutely necessary in producing gray iron. The 4 per cent. carbon iron when cast against a chill gave a white iron, but when allowed to cool by itself the latent heat given up by the separation of the carbon from solution prolonged the cooling and gray iron resulted. The 2 per cent. carbon iron even when allowed to cool by itself produced a white iron.

The high specific heat of carbon has its effect upon the rate of cooling of cast iron. Let us look for a moment at the atomic heat calculation. The specific heat of carbon at low temperature is 0.198; at 1800° it has been found to be 0.459. Figured from an atomic heat of 6.3 the specific heat should be 0.525. If the specific heat rose in proportion from 1800° upward, as it did from low temperature to 1800° F., we should have carbon with a specific heat of 0.525 at a temperature of about 3200° F. If we assume the temperature of our molten iron to be 2600° F. and the temperature at which further separation of the carbon as graphite or temper carbon ceases to be 1800°, then we have 800°, in which the cooling of the iron affects the condition of the carbon, and hence the quality of the iron. Let us assume the specific heat of the carbon in passing through these degrees of temperature to be 0.5, the per cent. of carbon in our iron to be 4, the specific heat of the iron to be 0.11, and the per cent. of the iron to be 96. The difference in specific heat between the carbon and iron would

be 0.39, or the excess in the amount of heat necessary to raise the unit of carbon one degree over the unit of iron would be 0.39. Hence in cooling there would be 0.39 times 4, or 1.56 heat units evolved over the normal amount which would be evolved by 100 per cent. of iron. In other words, the heat evolved by the carbon in cooling would decrease the rate of cooling of the iron and carbon by about one-seventh. When one considers the great changes which a small difference in temperature makes in the structure of cast iron the importance of this difference in the rate of cooling will be appreciated. The rate at which iron cools affects the structure of soft iron, more especially between its casting temperature and about 1800°. With hard iron, however, the rate at which it passes through the degrees down to 1200° has an effect upon the ultimate composition of the iron. No attempt has been made to make this calculation other than approximate. My object in introducing it is to show that the high specific heat of carbon delays the cooling of the iron and gives further time for the separation of carbon, and hence the evolution of latent heat.

I have previously alluded to a second factor which has an important effect upon the properties of cast iron. That factor is silicon. I have shown that carbon in separating from solution prolonged the fluidity of cast iron, in fact gave to cast iron the properties of a cast product. We then assumed a pure iron with carbon its only impurity. In practice this is never encountered, and while many irons with low silicon have an application as cast iron, yet in all cast irons silicon plays an important part. Pure iron under maximum conditions is said to dissolve about 23 per cent. silicon. Iron will then dissolve about three and one-half times as much silicon as carbon, and, moreover, carbon and silicon each reduce the solubility of iron for the other by an amount which is proportionate to their solubility. For example, an iron containing 23 per cent. silicon would dissolve no carbon, while an iron containing 6.67 per cent. carbon would dissolve no silicon. Proportionately an iron containing say 10 per cent. silicon would dissolve 3.8 per cent. carbon, etc. It must be remembered, however, that this would be under maximum conditions as to heat and purity. The high point of solubility of iron for silicon and carbon in the best brands in the United States is about 17. This

does not mean that the sum of the silicon and carbon percentages ever reaches 17, but inasmuch as iron absorbs about three and one-half times as much silicon as carbon before it becomes saturated, the 17 is the silicon percentage plus three and one-half times the carbon percentage. Irons for soft foundry work which run 15, when figured in this manner, might be called rich, 15.5 very rich, and 16 excellent, while 17 is exceptional and very seldom seen in ordinary foundry iron. The amount of carbon which an iron will contain when it comes from the cupola depends largely upon the amount of silicon. Silicon is chiefly useful as a softener, that is, as a producer of graphitic carbon. Iron will dissolve silicon more readily than carbon, as shown by the greater amount it will dissolve. This is probably due to the fact that the silicon molecule is simpler and more readily broken up than the complex carbon molecule, and that it contains a much less number of atoms to the molecule.

We have quoted Saniter's experiment to show that a high-carbon iron cooled slowly retained in the solid state 1.20 per cent. combined carbon. From this we conclude that the solubility of solid iron for carbon is about 1.20. If we assume this to be true, and our ratio of 3.5 to 1 holds good, then an iron containing 4.20 per cent. silicon, cast under the same conditions as Saniter's experiment, could hold no carbon in solution in the solid state. This we find to be essentially true in practice. Figuring in the same manner, an iron with 3 per cent. silicon would retain approximately 0.3 per cent. combined carbon; an iron with 2 per cent. silicon, 0.6 per cent. combined carbon, and an iron with 1 per cent. silicon, about 0.9 per cent. combined carbon. These results are sufficiently close to our actual experience to indicate that our assumption is correct.

The specific heat of silicon is 0.20, and thus the silicon retards the cooling to a certain degree on account of its specific heat. The 1.20 per cent. carbon held in solution in the solid state by iron containing no silicon may be forced from solution by silicon. The latent heat of solution of this carbon will prolong the cooling of the iron and give it fluidity, while the fact that the combined carbon has been changed to graphite will lend softness to the iron. This last 1.20 per cent. combined carbon, which is

forced from solution by the silicon, separates at or near the solidifying temperature and gives up its latent heat just when it is most needed to prolong the cooling, to increase the fluidity and softness and to decrease the shrinkage. High-carbon irons are always low-silicon irons, and high-silicon irons are always low in carbon. It would be possible to have a high silicon low-carbon and a low-silicon high-carbon iron of exactly the same hardness. The proportion of carbon to silicon is determined by the class of work for which the iron is intended. The difference in effect of carbon and silicon upon iron is very marked. It is this difference which gives carbon the advantage over silicon as a softener for cast work. No definite figures could be laid down as the best proportions to use of carbon and silicon for various grades of work. One thought should, however, be remembered. Silicon in iron is not a desirable factor. The per cent. of silicon used should be just sufficient to force from solution the amount of carbon desired in the free state in the work in question and to furnish the requisite fluidity for casting it.

The effects of phosphorus, sulphur, and manganese and their action on the carbon-silicon ratio should have a place in the paper, but time prevents my discussing them at this time.

THE IMPORTANCE OF ADOPTING STANDARD SIZES OF TEST-BARS FOR DETERMINING THE STRENGTH OF CAST IRON.

By Alexander E. Outerbridge, Jr.

It is a fact well known to founders, that the physical properties of cast iron, such as strength, hardness, ductility, coarse-grainedness or "fracture," etc., depend not alone upon the chemical constitution, but also upon the rate of cooling of the metal from the fluid to the solid state.

It is quite possible to obtain from one ladle of molten pig iron, castings having widely different physical properties, covering the entire range from hard white iron to soft gray metal, by simply regulating the rate of cooling of the iron when poured into the castings. This may be accomplished in a variety of ways, as follows:

1. Let us assume that we have metal of approximately the following composition in a ladle:

Graphitic carbon	3.00	per cent.
Combined carbon	0.75	"
Silicon	0.65	"
Manganese	0.15	"
Phosphorus	0.50	"
Sulphur	0.10	"
Iron	94.85	"

Suppose that we cast this metal into a solid wedge-shaped bar six feet long, six inches square at the thick end, tapering to one-quarter-inch square section at the thin end. If we break the bar into short pieces, say about six inches in length, we will find almost every grade of cast iron (as shown by the fracture) from white iron at the thin end of the wedge, to dark gray metal with coarse-grained fracture at the thick end. Between these two extremes we will find intermediate grades of cast iron. If we now cut from the gray portion of the bar, pieces of convenient size for tensile tests, we will find, on pulling them in a testing machine, astonishing variations in the strength of the metal.

A chilled cast-iron car wheel is a more familiar illustration of a casting having widely different physical properties in its different portions, depending upon the rate of cooling of the metal. The "tread" or rim, which is cooled quickly, is white iron, while the "plate" or body of the wheel, which is cooled more slowly, is gray, and the hub, which "sets" still more slowly, is usually quite soft, coarse-grained, dark gray metal. Tensile tests of the gray iron in the plate and of that in the hub of a wheel show great difference in strength. In one test the iron from the plate of a wheel gave tensile strength of about 30,000 pounds per square inch, while the metal from the hub of the same wheel showed tensile strength of less than 20,000 pounds per square inch. The metal from the plate was comparatively fine-grained, while that cut from the hub was coarse-grained.

2. If we should cast a solid block of iron, say about 15″ x 15″ x 15″, and should plane off the surfaces, then cut up the block into a large number of bars, say 1″ x 1″ x 14″, for transverse and tensile tests, we should find an enormous difference in the strength of the metal from different portions of the casting, the bars from the center of the block would be much weaker than those from the outer portion, while the fracture would show very much coarser grain and darker color in the bars cut from the interior of the block as compared with those from the outer portion.

3. If we should cast several test-bars from one ladle of iron, all of the same length, say 15″, but varying in thickness, ranging, let us say, from $1\frac{1}{4}''$ to $2\frac{1}{4}''$ diameter, we would find if we should pull the bars on a testing machine, astonishing differences in tensile strength, the larger bars having, as a rule, much less strength per square inch than the bars of smaller diameter.

4. If we should cast several test-bars all of the same size, from one ladle of iron, and cool some of them rapidly, others slowly, we would find remarkable differences in strength and resilience of the bars, those which had been cooled quickly would, as a rule, be much stronger than those which were cooled slowly. I am assuming in all cases, except the first, that the metal would be entirely gray in the castings—*i. e.*, free from any tendency to mottled iron.

In the first case cited, I selected a "high-chilling" mixture

(low in silicon), corresponding to car-wheel iron, in order to present the greatest contrast in the physical properties of the metal in different parts of the wedge-shaped bar, ranging from white iron at the thin end to dark gray, coarse-grained metal at the thick end, as well as in different portions of a chilled cast-iron car wheel. It is not necessary, however, that we should select special metal for such tests, the law holds good for all grades and kinds of iron commonly employed for castings.

The second experiment referred to, viz.: the casting of a solid block of iron about 15" x 15" x 14", is not a hypothetical case, but was an actual experiment which I made in 1888, a brief description of which may be found in the *Proceedings of the Fifth Annual Meeting of the American Society for Testing Materials*, Vol. II., page 214. This block was cast from an ordinary foundry mixture such as is commonly used for miscellaneous castings. The block was planed and sawed into eight slabs of one inch thickness each, the slabs were then cut into bars 1" x 1" x 14", making in all sixty-four test-bars; they were numbered serially and then broken on a transverse testing machine with supports 12" apart. The highest records of strength were found in the outside rows, in accordance with expectation, the average breaking stress of the bars forming the bottom row, for example, was 2800 pounds, the fracture being close-grained. The bars cut from the center of the block were much weaker and the fracture showed very coarse grain. The average breaking stress of the bars from the center of the block was 1750 pounds.

For the third case (also an actual experiment) a fairly strong mixture was employed. Four round test-bars, fifteen inches long, were cast from one ladle of iron, two of the bars were $1\frac{1}{4}$" in diameter and two were $1\frac{5}{8}$" diameter, in the rough castings. The $1\frac{5}{8}$" bars were turned, for a length of 10" between shoulders, to a diameter of 1.128", giving an area of one square inch. The $1\frac{1}{4}$" bars were turned, for a length of ten inches between shoulders, to a diameter of 0.809", giving an area of 0.035 square inch, the ends being threaded for the grips of the testing machine. The following table, selected from a number of similar tests, will show the great difference in strength per square inch between test-bars $1\frac{1}{4}$" and $1\frac{5}{8}$" diameter, cast from the same ladle of iron:

Test No.	Date.	Rough Diam.	Finished Diam.	Sq. Inch Area.	Ultimate Strength lbs. per Sq. Inch.	REMARKS.
1167	2|27|'00	1 5-8″	1.129″	1.000	29,300	Fracture close grain.
1168	"	1 5-8″	1.129″	1.000	28,900	" "
1169	"	1 1-4″	.899″	.635	33,160	" "
1170	"	1 1-4″	.899″	.635	33,200	" "

Other similar tests were made corroborating the foregoing, and all tending to show the importance of adopting standard sizes of test-bars for determining the strength of cast iron when poured into castings of different dimensions.

Records of tests of cast iron are useless, for the reasons here given, unless the rough dimensions and finished sizes of the bars are stated. Recently, for example, an excellent paper on "Melting Steel with Cast Iron" was read before the New England Foundrymen's Association, and printed in extenso in many technical periodicals. Records were given of eighteen separate melts of cast iron and steel scrap, with complete chemical analyses of each melt, together with six tensile and transverse tests from each melt, making 108 breaking tests in all, but nowhere could I find any statement showing the dimensions of the test-bars, either rough or finished, so that it was impossible to make any use of these records for purposes of comparison. This is by no means an exceptional instance.

The rate of cooling of cast iron from the fluid to the solid state is such an important factor in determining the physical properties of the metal, that it is just as important to know the dimensions of the test-bars as it is to know the chemical composition. It is equally desirable, for the same reason, that standard sizes of test-bars should be adopted which would be suitable for different grades of iron.

At the present time the whole matter of testing cast iron is in such a chaotic state that few of the published tests are susceptible of comparison, one with another, or even of affording reliable information regarding the character of the metal. It is with the hope of drawing attention to this important subject that these brief notes are here presented showing a few actual tests that have been made, from time to time, during the past fifteen years.

DISCUSSION.*

Mr. Scott.

MR. SCOTT.—I think that each foundryman should use a test-bar of such form and size as may, in his judgment, give him the most reliable information of the material he is using. In cases of dispute an "arbitration" test-bar should be used of a standard size and shape and made under fixed conditions.

Mr. Moldenke.

RICHARD MOLDENKE.—The American Foundrymen's Association went into this matter of test-bars probably more thoroughly than anyone else, and the underlying principle was to get such a series of bars that one or more could be picked out of which it could be said that all external deleterious influences were absent. Hence, round and square bars, rough and machined ones, green-sand and dry-sand bars, all of them cast on end, to avoid the difference of strength on the cope and drag sides when cast flat, were prepared. These bars were made from twelve kinds of iron, and the results indicated very plainly that a $1\frac{1}{2}$-inch round test-bar came nearest to the ideal one. It further developed that what we wanted was not so much the value of the particular casting a bar was supposed to represent, as every founder knows that this is only a rough and sometimes a bad approximation, but a system which would give the true value of the iron used, all influences tending to better or destroy its inherent characteristics being absolutely cut out.

As we all know, however, that everyone will continue to use his favorite bar, whether we decree to the contrary or not, the idea of the "arbitration" bar is worthy of our best consideration. Since such a bar would be used only when disputes arise, it can be made with special care and at some extra expense, as it will serve as a means of settling important commercial disagreements. Such a bar may solve the present difficulty, and it is to be hoped that the committee will agree on something of the kind.

Mr. Field.

H. E. FIELD.—I should like to say a word on the test-bar question. I happen to be a member of the sub-committee of

* See also Discussion on Test-Bars, pp. 43 and 44.

which Mr. Souther is chairman, and gave considerable time to the letter which he sent out. This letter asked for the opinion of the members of the committee concerning a standard bar of definite size. There seems to be a great difference of opinion concerning this test-bar question. Some claim that the bar should be of one size and that this should be of a section which would most clearly represent all cast iron. Others contend that a test-bar should be of such size and shape and cast under such conditions as to most clearly represent the strength of the casting or castings with which the bar is cast. One contends for a test of iron in the abstract, the other for a test for iron in casting. The first is of theoretical value, the second of practical value. In connection with some work for the Government, which included carriages for guns and mortars and castings for various-sized shells, I came to the conclusion that the test that most clearly corresponded with the strength of the casting was a hollow cylinder the thickness of the walls of which corresponded to the thickness of that part of the casting which was to stand the greatest strain. For shells the diameter and thickness was made to correspond to that of the shells. For large castings a cylinder 14 or 15 inches in diameter with a core varying in diameter so as to produce the required thickness, gave very satisfactory results. If the castings are excessively heavy and the part on which the greatest strain comes is relatively light, the core should be made smaller and set to one side of the cylinder, leaving a thickness on the thin side which shall correspond with the thickness of the part of the casting which stands the greatest strain. The large body of metal in the rest of the cylinder will cause it to cool under similar conditions to the casting with which it is cast. The cylinder may be made from 10 to 16 inches in length according to the length of the test required. The cylinder is strapped on a planer and a piece cut out with two tools set in one head of sufficient size to allow a test plug of the required size and shape to be turned out. Mr. Field.

If we are to adopt standard tests for cast iron, we should make these tests sufficiently flexible to include all grades of castings. If you were going to cast a shell $\frac{5}{8}$ inch thick, and a cylinder 4 inches thick, each required to stand a tensile strength of 30,000 pounds per square inch, you would not put the same iron into

Mr. Field. both; if you did, you would not get 30,000 pounds per square inch in both. I cannot therefore see the logic in adopting a single-size test with which to test both. A previous speaker has said that we do not want to get the test which will be interfered with by the sand in which it is cast. I differ strongly on this point. I think that the test should be subjected to the same conditions as to sand, etc., as is the casting which it is supposed to test. In other words, I hold that what is needed is a better knowledge of the strength in our castings, and not what the iron will bring in some special-sized test-bar which may or may not give the same results as the iron in the casting.

Mr. Wood. WALTER WOOD.—I think there is a great deal of value in Mr. Field's suggestion that in order to fairly represent a given casting, the test-bar should be made under similar conditions and of a special shape. But, after all, is not that an individualization of the test-bar rather than its standardization? If our committee agree first on the standardizing of the bar, the question of individual bars to fit a particular kind of work may be afterward considered. This course, it seems to me, will lead to quicker results.

Mr. Outerbridge. ALEX. E. OUTERBRIDGE, JR. (by letter).—The "Arbitration Bar," since proposed by our Committee B, on "Standard Specifications for Cast Iron and Finished Castings," which is a round bar cast, on end, $1\frac{1}{4}$ inches in diameter and 15 inches long, is the same as the bars of tests Nos. 1169 and 1170, given in the paper under discussion. As these bars, made of "a fairly strong mixture," gave tensile strengths exceeding 33,000 pounds per square inch, it will be seen that the requirements as to tensile strength of the arbitration bar (ranging from 18,000 pounds per square inch for light castings to 24,000 pounds per square inch for heavy castings) are extremely moderate, and should not be at all difficult to fill.

THE DEMAND FOR A SPECIFIED GRADE OF PIG IRON.

By W. G. Scott.

The present period may be justly termed the "Iron Age," or rather the beginning of such an epoch, as iron and steel are the most important metals known to commerce. Imposing structures of steel are replacing buildings of wood, and steel bridges attest their superiority in all parts of the world, while machinery and agricultural implements formerly made in greater part of wood, are now constructed almost solely of iron or steel.

Great progress has been made in the manufacture of steel, in fact more than in any other branch of metallurgy, and this advancement is due chiefly to the science of chemistry. No great advance has been made in the manufacture of wrought iron, and only recently has there been much improvement made in the methods of producing pig iron.

When pig iron was graded and sold by fracture, the main point considered was in the production of a close or open-grained iron. An open-grained iron was supposed to be soft, while a close grain indicated hardness and strength. The iron was graded by fracture and the grades numbered according to the size of the crystals, a very large crystal or open-grained iron being designated as No. 1 Foundry, or No. 1 Soft; a somewhat closer grain was termed No. 2, and a still closer grain No. 3. Mottled and white iron with their higher numbers were distinct grades, but the difference in grade of the lower numbers was not always clearly defined.

There is no question but what the fracture is in a measure an indication of the temporary hardness or softness of the iron, but we now know that the effect of the temperature in changing the form of the carbons not only affects the hardness but governs the size of the crystals. In an iron quickly cooled the crystals are small, and the iron generally hard, owing to the fact that the graphitic carbon has been changed to the combined form. Slow cooling favors the formation of graphite and produces an open grain, the iron being generally soft.

The pig-iron man has known this for years, and since the advent of applied-iron chemistry he has learned how to produce a pig iron with a given chemical composition: in fact, he can fill an order and comply with the terms of a specification limiting certain metalloids to a fraction of a per cent. He has learned the proper temperature in melting so as to produce an iron high in silicon and low in sulphur; the kind of flux necessary to produce an acid or basic slag in order to increase or decrease manganese, carbon, etc. He has learned how to mix different ores so as to produce an iron of definite composition; furthermore, he is still learning, and the result will be that the process of pig-iron making will soon rival that of steel.

The most important factor in the advancement of steel-making was in the production of a material strictly complying with the terms of a certain line of specifications; consequently, in order to fulfil the rigid terms implied, all guesswork and rule-of-thumb methods were discarded and the science of metallurgical chemistry installed.

If science and chemical knowledge can produce with certainty a uniform grade of steel, it is reasonable to expect a certain degree of improvement in the parent industry whereby a grade of pig iron may be made to comply with the terms of a simple specification in this line. Admitting that it is often a difficult operation to produce a strictly uniform grade of pig iron, and the process not so easy to regulate as that of steel-making, yet it is possible to furnish a pig iron with a given composition.

The blast furnace buys its ore on analysis, and not by color or fracture, and the time is now at hand when the American foundryman must buy his iron in a similar manner, to meet the increasing demand for castings of a specific composition, given strength, etc. When iron is sold on specification and the shipment accepted, the pig-iron man is relieved from all future annoyance, and cannot be blamed for poor results due to high-sulphur coke, poor molding, etc.

On the other hand, iron of unknown composition, bought by fracture, has to stand the brunt of all the trouble in the case of a poor heat or lot of bad castings; in fact, nine times out of ten the iron receives the blame and the agent is requested to take back

the iron, which he usually does, as he dislikes to lose a customer. Many concerns employing a chemist make it a rule, under the fracture method, to buy a No. 2 pig iron, experience having taught them that much of this No. 2 iron is high enough in silicon and low enough in sulphur to rank as a true No. 1 iron. The difference in price helps to maintain the laboratory, and the blast furnace is not informed as to the true grade, but in the event of a No. 2 iron showing on analysis a composition equivalent to a No. 3 or No. 4 iron, the agent seldom fails to receive a hint as to its inferior quality.

The conclusions to be drawn from the above are that the blast furnace and the foundry should work in harmony, settle upon an iron graded in accordance with its composition, and define certain methods for sampling and testing the material. The blast-furnace chemist usually takes a "shot-test" sample of a part or the entire cast for analysis, while the foundry chemist takes a certain number of pigs from each car for an analysis, consequently there may be a decided difference in their assays, for the reason that the first part of the heat in a pig bed may be higher or lower in silicon or sulphur than the latter end of the heat, accordingly as the furnace is working hot or cold, whereas a sample taken from a car lot might represent one end or the other of such a cast, therefore some provision should be made for this feature in sampling. In sampling from a car, I believe that not less than ten pigs should be taken as an average; furthermore, that the drillings should be from the freshly fractured face of the pig, and that the borings be made about midway between the centre and outside.

In regard to grading pig iron by analysis, I would suggest that the different varieties be divided into the following classes, viz.: "Foundry Pig," "Ferro-silicon," "Manganese Pig," "Phosphoric Pig," "Charcoal," and "Malleable Bessemer." In this way the class name would be a distinctive indication of the character of the iron, and simplify the specification matter. Specifications have become an essential feature in all commercial and Government transactions, and the tendency to buy by specification is stronger now than ever.

Dr. Charles B. Dudley deserves the credit of being the pioneer

specification maker, and his work in this line is one of the leading features of the Pennsylvania Railway System. The success of these specifications was an incentive to other firms, and in a short time it led to the universal custom of buying steel and other material in a similar manner.

With the advent of Professor Howe's "Metallurgy of Steel," Thomas West's "Metallurgy of Cast Iron," and Dr. Moldenke's literature on Melting Points, Foundry Manipulation, etc., there was created a desire to include all kinds of metal in a suitable form of specification.

During this period the writer was instructed by the management of the J. I. Case Threshing Machine Company, the Milwaukee Harvester Company and other concerns to formulate a set of specifications for pig iron. The undertaking was somewhat difficult, as it was necessary to visit a great many factories using different grades of iron; to study blast-furnace conditions; work out numerous experiments, and make a great many analyses of various grades and brands of pig iron.

The first set of specifications drawn up were found to be somewhat too rigid in regard to phosphorus and manganese, consequently were soon revised, and are now in general use. The call for a copy of this specification by foundrymen and chemists in this country and abroad has exhausted the second edition of 5000 copies, this showing conclusively that there is a desire for a specific grade of pig iron otherwise than by fracture.

CAST IRON FOR DYNAMO AND MOTOR FRAMES.

By H. E. Diller.

In designing a dynamo or motor, the engineer uses a large factor of safety in his calculations, which in some instances is even greater than 30 per cent. This extra allowance is necessitated partly by his limited knowledge of the exact properties of the materials which he puts into his machine, but mostly by the irregularities in their quality. These irregularities in the iron and steel used are sometimes of such magnitude that, notwithstanding the large margin allowed by the designer's calculations, a dynamo of the same type as many which have previously made a splendid showing in the shop test will, when put on trial, fail to develop the required output. So besides the waste of material and other losses entailed in using an excessive amount of metal in the machine, there occasionally is the expense of dismantling the dynamo after it is tested, to add more turns of wire to the field coils.

To get a good material of a regular quality should be the earnest effort of every manufacturer of electric power apparatus. The permeability and the hysteresis loss of iron and steel depend primarily on the heat treatment they have undergone, and on their chemical composition. In making sheet steel for armatures and laminated pole pieces, and steel castings where high permeability is required, it is endeavored to keep the amount of elements other than iron as small as possible. Sheet steel is made with as high as 99.7 per cent. of iron, while the regular casts of some steel foundries contain more than 99.6 per cent. of iron. There are, of course, some steel works and foundries which sell steel containing large amounts of the undesirable elements; but in general we can look for considerably over 99 per cent. of iron in steel to be used for electrical purposes. In these purer steels the magnetic qualities are dependent more on the mechanical and heat treatment to which the steel is subjected than on variations in its chemical composition.

But in cast iron we have a somewhat different problem. Here the elements present, other than iron, are a far greater factor in determining its physical and electric qualities, amounting, as they frequently do, to over 7 per cent. Of carbon, which exerts the most influence on its permeability, there is frequently more than 3.5 per cent. existing in the two destructive states—graphitic and combined—while in steel for electric purposes the amount of carbon should always be less than 0.2 per cent., all of which exists in the combined state. If we wish to know something of the heat treatment a steel casting has received, we must have recourse to the microscope to show us the size of the crystals and the form in which the carbon is blended with the iron to form the pearlite. On the other hand, the combined carbon in cast iron will tell us a pretty clear story of the rate of cooling, and of its physical condition. Then, too, the iron casting is not annealed, while all steel for frames, armatures, and pole pieces should be annealed.

After this rather long introduction, I would like to consider more specifically the requirements of cast iron for use in dynamo and motor frames, and the problems it presents to the designer, more especially as to its magnetic properties. In large frames the strength and rigidity of the metal is usually of primary importance, while in medium and small-size frames the strength problem is almost, if not entirely, eliminated, and the permeability of the iron is the governing factor, especially where an effort is made for a neat machine which will present a pleasing appearance and where excessive weight is prohibitory, as in the case of ceiling motors and machines to be placed in tall factory buildings. For both of these qualities—strength and high permeability—the thing most essential is a low percentage of total carbon in the iron.

A company which buys its castings from different foundries gets castings which vary widely in their magnetic properties, and even when a company makes its own castings, it is only with the greatest care in the mixing and melting of the iron that they are able to get a regular product. These irregularities in the iron make it greatly desirable for the engineer to know the permeability of the dynamo and motor frames. To tell this there have been

several kinds of permeameters designed, none of which, I believe, claim to give more than approximate results. Another way is to cast several bars during the heat and test them in the laboratory permeameter. But as these bars are usually of considerable lighter mass, they cool more rapidly than the cast frames, thus getting a higher percentage of combined carbon, and consequently have a lower permeability than the iron in the frames. This difficulty can be considerably overcome by casting a bar on each frame, but this necessitates considerable labor in clipping off the bars and turning them to the required dimensions.

But I believe the magnetic properties of cast iron depend almost entirely upon its chemical composition, and think that with a good knowledge of iron and with a proper care as to the melting and mixing of the charge, a regular grade of first-class castings can be made, which will have practically the same permeability. In a general way we may say that the less of each element, other than iron, in an iron casting the higher is its permeability.

The amount of sulphur is kept as low as possible in all castings, except occasionally when high sulphur is desired to increase the chilling properties of the iron. This rule is a good one for iron to be used in making dynamo and motor frames. But the amount of sulphur in the ordinary cast iron is so small that of itself it does not noticeably affect the permeability of the iron. Indirectly, though, it is very detrimental, as it tends to increase the combined carbon and causes blow holes. However, its effect of combining the carbon can be neutralized by putting a larger amount of silicon in the iron.

The phosphorus in cast iron varies from about 0.15 per cent. to 1.4 per cent. But in ordinary machinery castings we generally find about 0.5 per cent. This is a considerable amount, but does not greatly affect the permeability of the iron. In looking over the curves given by different irons whose phosphorus contents range from 0.16 per cent. to 1.2 per cent., I could trace very little effect on the permeability due to the phosphorus.

With manganese it is quite different, for its presence in large amounts markedly lowers the permeability of iron. It is difficult to get bars which vary in manganese but still have the other

elements the same. After comparing a great number of curves and making due allowance for the variation of the other elements in the iron, it seemed that a variation in manganese makes almost as much difference in the permeability as does an equal variation in the amount of combined carbon. Fig. 1* shows two curves given by iron with the manganese—in 5A 0.50 per cent., and in 7A 1.4 per cent. The total carbon in 7A is slightly higher than in 5A, and will about neutralize the effect of the higher combined carbon in 5A; so we can practically attribute the difference in permeability to the difference in manganese. At 20 ampère turns per centimeter length this difference amounts to about 1800 lines per square centimeter, and the curves then run almost parallel

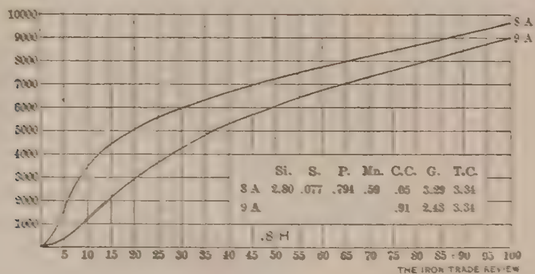


FIG. 1

through the higher densities. The effect of graphite seems to also be the same in the lower as in the higher densities, but we find a difference in the effect of combined carbon which is not nearly as strong in the higher as in the lower densities. The curves on Figs. 2 and 3 show good examples of this.

The percentage of carbon existing in cast iron as graphite or combined carbon depends on the amount of manganese, sulphur, and silicon present, the size of the casting, and the rate of cooling. With enough silicon in the iron we can reduce the combined carbon to less than 0.10 per cent. The silicon of itself has very little detrimental effect on the permeability of the iron, and so it seems best to have a large percentage of silicon in the iron in order that we always have a dead soft casting. This will eliminate

* Acknowledgment is made to the *Iron Trade Review* for the use of the cuts appearing in this paper.

one of the most serious causes of irregularity in the iron, as the amount of combined carbon present has a marked effect on the permeability. Curves on Figs. 2 and 3 are good illustrations of this. Curves 1A and 2A are from different bars cast from the same ladle of iron, as are also curves 8A and 9A, the higher combined carbon in 1A and 9A being obtained by a faster rate of cooling.

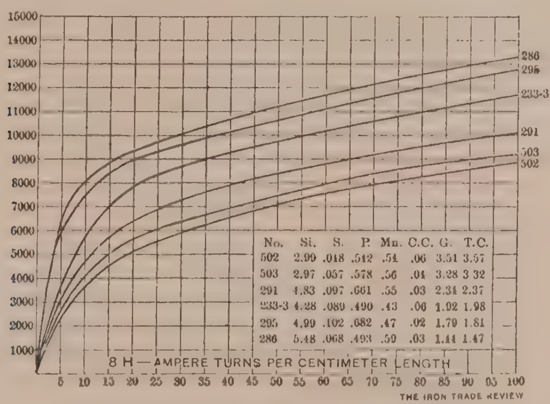


FIG. 2.

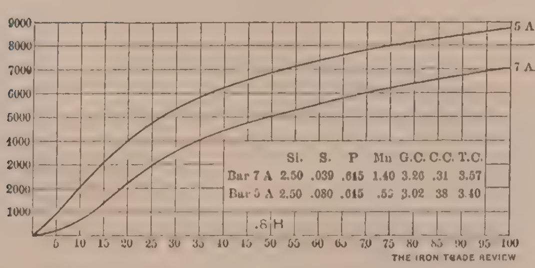


FIG. 3.

With the amount of combined carbon controlled by the silicon, and the percentage of manganese easily regulated in making up the charge for the cupola, the only considerable cause left for irregularity in the permeability of the iron is the amount of graphite present. It is difficult to regulate this, about the only way being the use of low-carbon pig iron or the addition of steel scrap to

the charge. But the fact that the iron takes up carbon from the coke it is melted with and that the iron melts at a lower temperature than the steel make it difficult to control with a great degree of accuracy the amount of carbon in the casting. On Fig. 4 are some curves showing the effect of graphite on the permeability. These curves I selected out of a great number because the combined carbon in all cases is so low as to be practically negligible, the manganese too is quite regular, and the curves are, I believe, good representatives of each class of iron. There is a big difference in the amount of graphite in these irons, varying as it does from 1.44 per cent. to 3.51 per cent., and also a wide difference in the permeability. The point which seems most interesting is that instead of increasing in direct proportion

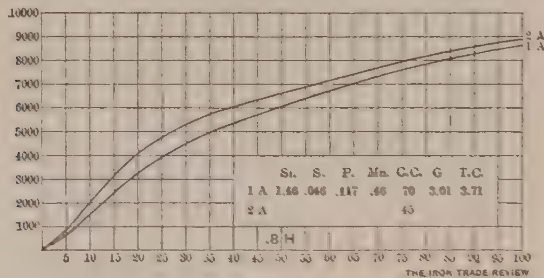


FIG. 4.

as the graphite decreases there is a great change in the permeability when the graphite is about 2 per cent., while the effect on the permeability due to difference in graphite is considerably smaller in iron having over 2.5 per cent. or under 1.7 per cent. of graphite.

Some of the foundries making rolls and special gray-iron castings and nearly all malleable-iron founders find it profitable to use the open-hearth furnace, even though it does cost a little more to melt their iron than it would if they used the cupola. Probably it will not be long until the manufacturers of electrical machinery will find it desirable to install open-hearth furnaces to do the work of the cupolas, and then the metallurgist can have the pleasing satisfaction of making regularly a good casting of high permeability.

THE LIGHT ALUMINIUM ALLOYS.[1]

By Joseph W. Richards.

Pure aluminium, like pure gold, silver, or copper, is a comparatively soft and weak metal; it has many of the properties of copper, being easily cut by a knife and having a fibrous, silky fracture. The pure metal hardens quickly while being worked, faster when worked cold, and becomes harder, denser, more elastic, and stronger, but soon goes to pieces if worked too far. The hard-drawn aluminium wire or hard-rolled sheet or rod have strong physical resemblances to hard-drawn or hard-rolled copper. To produce thin sheet or fine wire it is necessary to anneal frequently, to remove the strains caused by the working. Castings of aluminium, unworked, are soft and weak.

The following table gives the usual limits of physical properties of No. 1 commercial aluminium, which averages 99 to 99.5 per cent. pure:

	Elastic Limit. (Lbs. per Square Inch.)	Ultimate Tensile Strength. (Lbs per Square Inch.)	Percentage Reduction of Area.
Castings	8,500	14,000 to 18,000	15
Sheet	12,500 to 25,000	24,000 to 40,000	20 to 30
Wire	16,000 to 33,000	25,000 to 55,000	40 to 60
Bars	14,000 to 23,000	28,000 to 40,000	30 to 40

For all purposes where the rolled, drawn, or worked pure metal is sufficiently hard and strong, it is advisable to use the pure metal, since it resists alteration by the atmosphere and other corroding agencies better than almost any of its alloys, and better the purer it is. For cast articles and wire, rod, or sheet which are not sufficiently strong or hard when made of the pure metal, the aluminium can be alloyed with small quantities of other

[1] A considerable proportion of the data in the above paper was acquired by the writer in experiments made in the metallurgical laboratory of Lehigh University, to which institution he wishes to express his sense of obligation.

metals, which improve it in various ways, without materially increasing its specific gravity. Pure aluminium has a density of 2.6 to 2.7, while the light alloys of which we shall treat contain up to 35 per cent. of foreign metals, and range in density from 2.4 to 3.6. The principal metals which have been proposed or used for these alloys are zinc, copper, nickel, magnesium, titanium, tungsten, chromium, manganese, and silver.

ALLOYING THE METALS.

The components of the alloy should be of as pure a quality as it is possible to get them. The aluminium used should be of No. 1 quality, which averages now 99.5 per cent. aluminium. For the very best results, the extra quality, sold as 99.75 pure, should be used. The commercial qualities of the other metals are frequently so impure that they give alloys of quite different properties from the pure metals. This is particularly true of zinc, the ordinary Western brands of which contain 1 per cent. or more of lead, and often considerable iron. In this case, it pays to purchase the redistilled zinc or the best varieties of Bertha or Sterling spelter.

As a general rule, it is advisable to melt the aluminium first, and then to stir or dissolve the other metal into it. Most metals, particularly copper, unite with aluminium with considerable energy, and dissolve quickly in it, even though their melting-point may be considerably higher. To facilitate the solution of a metal of very high melting-point, such as nickel, it is advisable to prepare first an alloy of the metal with aluminium in somewhat like equal proportions. This alloy, cast into bars, is then added to the melted aluminium, and dissolves much faster and more uniformly than the pure metal.

The melting can ordinarily be performed in graphite or plumbago crucibles in a melting-hole. The crucible should stand on a refractory pedestal, to keep the bottom from being chilled should the fuel be burnt out beneath it, and to avoid it tipping. It should be covered tightly, in order to avoid absorption of gases, or the accidental dropping in of coke. If the alloying is being

performed, the metal is best kept covered with lumps of charcoal, to keep air from striking the surface, but this is not needed or recommended if the operation is simply a melting.

Since the fire is hotter than the crucible, and the crucible walls hotter than the metal inside, it is of great importance that the fire be not too hot and the metal not overheated. Aluminium alloys, like aluminium, have large specific heats, and it takes a large amount of heat, though not a high temperature, to melt them. The characteristic of the furnace operation is therefore to have only a moderately hot fire, and then wait with patience until the metal melts, which will take from 30 to 50 minutes, starting with a cold crucible. The disadvantages of overheating the metal are three, viz.: it absorbs more gases, it will probably be poured too hot and segregate in the mould, it will react on the crucible itself, reduce from it iron and silicon, and become brittle. It is of the greatest importance that the alloy be never over a cherry-red heat, and it should never adhere to or wet the crucible. The stirring rod may be iron, preferably a wrought-iron bar, if the temperature is carefully kept low. If the temperature is too high, the iron bar will be wetted and corroded and the alloy injured. Until experience has been gained, it is better to use a carbon rod for a stirrer, fastened into the end of an iron pipe, for a handle.

When the alloying metal has been all dissolved, the whole is stirred vigorously, and cast at once. Letting it stand some time in the furnace produces a somewhat closer alloy, but the deterioration caused by increased gases and impurities taken up from the crucible usually overbalances the gain. After taking from the furnace, the crucible should be placed on some fire-bricks and stirred as it cools, and should be cast only just hot enough to properly fill the mould. If cast too hot, it is apt to segregate while cooling.

The use of a flux in the crucible is in no case recommended, since it attacks the walls of the same, facilitates the reducing action of aluminium upon them, and injures the alloy. With careful regulation of temperature and use of no flux, a good crucible will last almost indefinitely, not being wetted or corroded. Iron skimmers or ladles may be coated inside with a wash composed

of finely ground bauxite mixed with a little lime. This is practically unattacked by any alloy. Magnesia-lined crucibles are best for this work, when they can be gotten.

With some metals there is a limit to the amount which aluminium can take up. Thus, it can keep in solution only 1.92 per cent. of lead, or 3.39 per cent. of cadmium, while it will mix with most of the other metals in all proportions.

MELTING-POINTS.

Almost all the light, strong alloys melt easier than aluminium. The addition of a few per cent. of any metal to aluminium lowers the melting-point, even though the metal added has a high melting-point. There is a limit, however, in some cases, to the amount of foreign metal which can be taken up without increase of melting-point. Adding copper, the melting-point decreases until 33 per cent. of copper is present, above which it rises. Antimony is the most striking exception, for small quantities increase the melting-point very considerably; 33 per cent. of antimony makes an alloy melting only at 230° higher than aluminium and 250° higher than antimony. Of the commercial alloys, however, containing small percentages of zinc, copper, nickel, or magnesium, it may be said that they melt either as easily as, or slightly more easily than, aluminium itself.

SPECIFIC GRAVITY.

The alloys with magnesium, 2 to 12 per cent., are the only ones which are lighter than aluminium itself; but they are lighter than their composition and the specific gravity of magnesium (1.72) would lead us to expect. Thus, 10 per cent. of magnesium would theoretically make a physical mixture with a specific gravity 0.16 less than aluminium, whereas it really gives an alloy 0.24 lighter. This points to expansion taking place during alloying in this case. In the case of the other metals, heavier than aluminium, their specific gravity is usually higher than would be calculated from the composition, pointing to a condensation or contraction taking place in alloying. In fact,

with small percentages of copper, iron, and nickel the contraction taking place in alloying is so great that the alloy occupies less volume than the aluminium alone entering into it. In these cases it appears as if the molecules of alloying metal slip in between the molecules of the aluminium, thus accounting for the increased hardness and tenacity of the alloy. The magnesium alloys range from 2.4 to 2.57 in specific gravity; the heavier metal alloys from 2.6 to 3.6. In general, the light aluminium alloys are one-fourth to one-half as heavy as the structural metals which they replace.

MOLDS.

For general castings, a loose-texture green sand is suitable. Numerous air vents must be supplied, and a large casting gate and heavy feeders at heavy parts of the casting. In such molds the alloys are poured cold, and as fast as possible, to prevent chilling. In spite of this, the slow cooling renders the alloy ununiform by segregation, and therefore not so strong as chilled castings. To partly avoid this, the castings are shaken loose from the sand as soon as they are set.

Slabs and rods for rolling and drawing are cast in chill molds, as are also any objects needed in large quantities. This makes the material soft, uniform, and stronger than if cast in sand, with a smoother surface.

WORKING AND ANNEALING.

All these alloys are hardened and stiffened by working, and must be frequently annealed to avoid cracks and breaks. The slabs and billets are best broken down while warmed to 150° to 250° C., under a steam hammer; afterward steel rolls with good surfaces are used, and about as much power is required as rolling hot steel of similar section. Imperfections in the casting must be scraped or gouged out before breaking down. Slabs are usually rolled two passes lengthwise, increasing the length 20 per cent., and are then turned 90°, and rolled out farther. The rolls should be at 150° to 200° C., and if polished sheet is required the sheet

is polished before being sent through the final polishing rolls. Working raises the tensile strength, but decreases ductility, and frequent annealing is necessary.

The annealing is done in a muffle, if possible, as it is advisable not to subject these alloys, especially magnalium, to the direct action of the flame, since absorption of gas and internal oxidation, or burning, takes place at redness without melting. Slabs and bars are heated to full dark red, so that a pine stick carbonizes when drawn over it. Sheet must not be heated so high; a thin sheet is merely warmed to about 400° C. and then cooled in water. Very thin sheet can be put into hot oil and this allowed to cool slowly.

Dipping and Frosting.

Alloys with magnesium or zinc can be given a pure, white, silvery surface by putting into a 10 per cent. caustic soda solution, containing 2 per cent. of common salt and warmed to 60° C. The object is kept 15 to 20 seconds in this, until a violent evolution of gas appears, then washed in cold water and brushed; then dipped 10 to 15 seconds in concentrated nitric acid, again washed in cold water, and then dried in fine warm sawdust. The soda solution is held in an iron vessel; the nitric acid in clay, porcelain, or slate. The dipping is particularly recommended for rolled slabs, after the first annealing, as any casting defects are thus shown up, and can be eradicated by cutting out or using emery paper. By repeated dipping, a fine silky matte is obtained, which is absolutely unalterable in air. For alloys containing copper or nickel, the soda solution is replaced by dilute hydrofluoric acid. A dull black finish may be obtained by using dead India-black varnish, and keeping one hour at 100° C.; a shining black can be obtained by using black stove varnish, and keeping 1 to 1½ hours at 50° C.

Alloys with Chromium.

Chromium hardens aluminium strongly, the alloys having somewhat of the qualities of self-hardening steel, *i. e.*, retaining their hardness on heating or after annealing much better than

any other of the aluminium alloys. Two to three per cent. of chromium is recommended as making the metal much harder, but decreasing malleability considerably. Eleven per cent. makes the alloy brittle, crystalline, and unworkable; three and a half per cent. makes an alloy which can be hammered and rolled, but is very stiff and "crackelly." Its mechanical properties are given by Lejeal as:

	Tensile Strength. (Lbs. per Sq. In.)	Elongation. (Per Cent.)
Hard-rolled	18,000	12
Annealed	17,500	7

Professor Langley made 2 and 3 per cent. alloys by dissolving chromium oxide in a bath of melted fluorides of aluminium, sodium, and calcium, and then pouring in metallic aluminium in the required quantity. Chromium alloys are being used commercially at present, but the writer cannot say to exactly what extent.

ALLOYS WITH TITANIUM.

Alloys up to 7 per cent. of titanium have been made, but the best is that with 2 per cent. This has elasticity comparable to spring brass, and a tensile strength of 30,000 to 35,000 pounds when rolled hard, with 3 per cent. elongation, and 21,000 pounds when annealed, with 16.5 per cent. elongation.

These alloys are difficult to make, as pure titanium is rare, and the only practicable method of manufacture is to dissolve titanic oxide in melted cryolite and add aluminium, which latter reduces the oxide and forms an alloy with the metal. If chromium oxide is added also, a triple alloy of chromium, titanium, and aluminium is obtained, which is very hard and rigid, and holds a cutting edge fairly well.

The titanium alloys have a dull, leady color and are corroded more rapidly than many other of the aluminium alloys, so that their use has practically disappeared.

ALLOYS WITH MANGANESE.

A. H. Cowles patented some years ago the addition of manganese to commercial aluminium up to 5 per cent., producing

particularly hard and rigid alloys. They can be made either by making a rich alloy of manganese and aluminium in the electric furnace, and diluting this down with pure aluminium, or by adding manganese oxide to the electrolytic bath in which aluminium is being produced, in quantity sufficient to form the desired alloy with the aluminium of the alumina being decomposed. The addition of rich ferro-manganese to aluminium also serves to produce the alloys, but has the disadvantage of introducing some iron and carbon into the alloy at the same time.

Susini makes a series of alloys of aluminium with 3, 5, 8, or 10 per cent. of alloying metals, the latter being zinc, copper, and manganese. He makes the alloy of the three latter in a graphite crucible, melts the required quantity of aluminium at a red heat, and then pours the liquid alloy into it. The three alloys he recommends most contain, in percentages:

Manganese.	Copper.	Zinc.
1 to 3	1.5	0.5
1 to 5	2.5	1.0
2 to 8	4.5	1.5

Used with copper and nickel, manganese makes the *hardest* light alloy of aluminium yet produced.

ALLOYS WITH TIN.

The alloy of aluminium with 10 per cent. of tin was strongly recommended by Mr. Bourbouze. It is whiter than aluminium, its density is 2.85, its coefficient of expansion by heat is less than that of aluminium, and it can be more easily soldered than pure aluminium. The tensile strength of a casting of this alloy showed only 14,000 pounds per square inch, with 4 per cent. elongation, so that it is no stronger than pure aluminium, and not as ductile. The alloy is said to be improved by the addition of 3 per cent. of nickel. As far as the writer is informed the use of this alloy has disappeared.

Tin is still used in some of the other light aluminium alloys, in small quantities of not over 2 per cent., to contribute to the easy fusibility of the alloy and to decrease the shrinkage. If phosphorus is simultaneously desired in the alloy the commercial

phosphor-tin is employed. The best material for soldering aluminium is an alloy of 29 parts tin, 11 parts zinc, 1 part aluminium, and 1 part of 10 per cent. phosphor-tin, patented by the writer's father. This alloy, however, is only 2.4 per cent. aluminium, and belongs to the heavy alloys.

ALLOYS WITH SILVER.

Aluminium will absorb up to 5 per cent. of silver without increasing in volume; the alloys thus made are whiter, harder, denser, and stronger than pure aluminium, and take a high polish, which they retain better than almost any other alloy of aluminium when exposed to corrosion. For the latter reason, particularly, they have been used since the early days of the aluminium industry, particularly when aluminium itself was almost as high-priced as silver, for opera-glasses, telescopes, statuettes, fine light weights, the beams and hangers of fine balances, fine instruments, and electric apparatus. Alloys up to 10 per cent. of silver can be worked, and 1 to 2 per cent. of copper is simultaneously used, to reduce the cost of the silver by partly replacing it. Alloys with 3 per cent. silver have been used for statuettes, with 5 per cent. for dessertspoons, fruit knives, and watch-springs, with 3 per cent. silver and 2 per cent. copper for balance beams, with 5 to 9 per cent. silver and 1 per cent. copper for cast dental plates.

Where cost is a secondary consideration, and fine grain, fine color, and inalterability are of first concern, the silver alloys are evidently still of some economic importance. The atomic weight of silver (108) is exactly four times that of aluminium (27), and their specific gravities are in the same ratio, and it is probable that this has some connection with the characteristic improvement in color, grain, and resistance to corrosion which these alloys show.

ALLOYS WITH NICKEL.

As far as the writer can find out, alloys of aluminium with nickel alone have not been found advantageous. Lejeal prepared an alloy with 4.5 per cent. nickel, which had a coarsely crystalline fracture, rolled and worked well, but had poor mechanical

properties. The commercial alloys which go under the name of "Nickel aluminium Alloy" are in reality ternary alloys of aluminium with nickel and copper. The alloys made for rolling contain 2 to 5 per cent. of nickel and copper together, the larger part being usually copper. The plates of the yacht "Defender" were made of this alloy. They were very satisfactory mechanically, showing an average elastic limit of 30,000 pounds per square inch, ultimate strength 40,000 pounds, with 10 per cent. elongation in 2 inches and 15 per cent. reduction of area. Its specific gravity was 2.75. The plates were unfortunately fastened in place by steel rivets and were not insulated from the Tobin bronze sheathing below the water line, with the consequence that the aluminium plates were badly corroded in two years' time.

What are called "Nickel-aluminium Casting Alloys" contain 7 to 10 per cent. of nickel and copper together, have a specific gravity of 2.80 to 2.85, contract 3-16 inch in setting, and have, in casting, an elastic limit of 8,500 to 12,000 pounds, ultimate strength 15,000 to 20,000 pounds, with reduction of area 6 to 8 per cent. A sample of this alloy tested by the Bethlehem Steel Company contained $3\frac{1}{2}$ per cent. of copper, *no* nickel, and had a tensile strength in casting of 15,000 pounds, with 1 per cent. extension. This test shows that buyers of commercial alloys should require a guarantee as to composition as well as mechanical properties.

The alloying of pure nickel with aluminium is not an easy matter, and is best accomplished by adding nickel oxide to the bath in which aluminium is being manufactured, or by reducing nickel oxide by an excess of aluminium itself, and thus obtaining a rich alloy of the two metals, from which the alloys with lower proportions of nickel can be manufactured.

ALLOYS WITH TUNGSTEN.

The precise effects of tungsten alone have not been very satisfactorily determined, since it is used in small amounts in conjunction with other hardeners of aluminium, such as with copper and iron, or copper and manganese, etc.

Le Verrier gives the properties of the alloy with 7.5 per cent. of tungsten as being:

	Tensile Strength. (Lbs. per Sq. Inch.)	Elongation. (Per Cent.)
Cast	22,000	1.5
Hard-rolled	35,000	4.0
Annealed	25,000	10.0

Such an alloy would be difficult to make, expensive, and not worth, mechanically, its increased cost.

Mannesmann, in making aluminium tubes, found that a fraction of 1 per cent. of tungsten made the metal stronger and increased its resistance to corrosion. Under the trade name of "Wolfram Aluminium," aluminium alloy with a small amount of tungsten has been used extensively for military equipments, the metal rolling, drawing, and spinning well without tearing or smearing the tools.

These alloys were made by adding tungstate of soda or tungstic oxide to the reducing bath in the manufacture of aluminium. At present, metallic tungsten in powder, made by the Goldschmidt process, is available for alloying, and the alloys can be made directly. In this way, several special alloys have been manufactured and have attained to somewhat extensive use in Europe.

Wolframium contains, according to an analysis by Minet, 98.04 per cent. aluminium, 0.375 copper, 0.105 tin, 1.442 antimony, and only 0.038 tungsten. It is therefore principally an antimony alloy, the antimony giving it good casting qualities, while the copper gives strength and the tin fusibility. It is difficult to see that any of its qualities could be influenced by so small a content of tungsten. The inventors (Reinhard and Roman) state in a very general way that manganese or nickel may replace more or less of the copper, tin, or antimony. Its color is like silver, it polishes finely, its resistance to corrosion is said to equal that of pure aluminium, it casts well in sand or chills, and rolls, draws, and works well generally. Its mechanical properties are stated to be:

	Tensile Strength. (Lbs. per Sq. Inch.)	Elongation. (Per Cent.)
Hard-rolled	52,000	2.14
Annealed	38,000	15.24

As this is a patented alloy, the above claims of the inventors may be taken *cum grano salis.*

Partinium, the invention of G. H. Partin, of Paris, contains 96 per cent. aluminium, 2.4 antimony, 0.8 tungsten, 0.64 copper, 0.16 tin. It is therefore much more of a tungsten alloy than the so-called "*Wolframium*." The inventor states, however, that the tungsten and antimony may be replaced in the alloy by magnesium, which would be an entire transposition of the composition of the alloy. Quite an extensive and noteworthy display of this alloy was made at the Paris Exposition of 1900, and it is quite possible that it is still in extensive use in France, particularly in the manufacture of automobile equipment.

ALLOYS WITH COPPER.

Copper is one of the most frequently used hardening agents for aluminium, being often used alone and often associated with zinc, nickel, and other metals.

Captain Julien, making experiments for materials suitable for airships, at the Park of Meudon, near Paris, obtained the following tests on sheet one millimetre thick, hard rolled:

Per Cent. of Copper.	Specific Gravity.	Tensile Strength. (Lbs. per Sq. Inch.)
0	2.67	26,500
2	2.71	43,500
4	2.77	44,000
6	2.82	55,000
8	2.84	56,000

In castings, these copper alloys are only slightly stronger than pure aluminium, because of the segregation of the alloy which takes place during slow cooling. It is only in chill-castings that satisfactory results can be obtained. Slabs and bars for rolling or drawing should be cast in chill-moulds.

German silver contains approximately 1 part zinc, 1 part nickel, and 3 parts of copper. Two to three per cent. of German silver alloyed with aluminium gives an alloy of approximately ½ per cent. each of nickel and zinc, and 1 to 2 per cent. copper. Such an alloy gives a tensile strength in castings of 22,000 pounds,

and in hard-rolled sheet over 40,000 pounds, with 3 to 5 per cent. elongation. This alloy, first described by the writer, is very elastic and of a fine white color, and is easily made by using commercial German silver, which contains the copper, zinc, and nickel already perfectly alloyed with each other.

ALLOYS WITH MAGNESIUM.

The following tests are furnished by the *Magnalium Gesellschaft*, of Berlin, as representing the properties of these alloys:

Per Cent. Magnesium in Alloy.	Tensile Strength. (Lbs. per Sq. Inch.)	Elongation. (Per Cent.)
2—Cast in sand	17,900	3.0
Cast in chills	28,600	2.0
Castings, water chilled	40,000	1.0
Annealed sheet	25,600	18.0
Hard sheet	41,300	2.7
4—Cast in chills	28,600	2.0
Annealed sheet	28,700	8.0
Hard sheet	44,900	2.1
6—Castings, water chilled	57,600	1.0
Annealed sheet	28,100	17.0
Hard sheet	44,100	1.0
8—Castings, water chilled	54,900	1.6
10—Cast in sand	21,400	2.4
Cast in chills	33,600	3.4
Castings, water chilled	61,100	4.2

These alloys have been patented by L. Mach. They cost considerably more than pure aluminium, because of the market price of magnesium being, in Germany, $1.00 per pound. The use of these alloys in Europe is reported to be already considerable and to be increasing. No data regarding their durability is yet at hand.

ALLOYS WITH ZINC.

Zinc is the cheapest and at the same time one of the most efficient of the metals which improves the mechanical properties of aluminium. Proportions up to 33 per cent. are used; the alloys are malleable up to 15 per cent., and above that are still useful

for making castings. Only the purest zinc and the purest aluminium should be used, to get the best alloys. Casting in chills gives much better results than casting in sand; in the latter case the slow cooling seems to cause a separation.

The alloys are made by melting first all the aluminium to be used, in a clean graphite crucible, bring it a little above the melting-point so that as the zinc is added, in small pieces, it does not chill the aluminium, but is all absorbed directly as it is added. The melting-point decreases as zinc is added, so that if the zinc is added slowly the alloy remains always melted. A wrought-iron rod can be used as a stirrer, if the heat does not at any time go above low redness. The metal should be poured as cold as is practicable; when much hotter than its melting-point it is not so thinly fluid as when somewhat cooler. The crucible should be kept covered while melting the aluminium, and no charcoal or flux put into the crucible, except, possibly, a little salt.

The alloy with 15 per cent. zinc can be rolled and drawn. In chill castings it has an elastic limit of 16,000 pounds per square inch, tensile strength 22,330 pounds, elongation 6 per cent. in two inches, and reduction of area 10½ per cent.

The alloy with 25 per cent. zinc has a tensile strength of 22,000 pounds, extension 1 per cent., and reduction of area 3 per cent., when cast in sand. When cast in chill-molds its tensile strength is 35,000 to 45,000 pounds, extension 1 per cent., with a close fracture like high-carbon steel. Its specific gravity is 3.4, which shows a contraction of 14 per cent. in the bulk of the constituents while alloying, and since 1 part of zinc has only one-eighth the volume of three parts of aluminium, the remarkable conclusion follows that the aluminium takes up one-third of its weight of zinc and actually decreases in volume some 2 per cent. in doing it. This probably accounts for the close grain and good working qualities of this alloy. It is non-magnetic, has a fine color, takes a high polish, and bids fair to be the most generally useful of all the light aluminium alloys.

The alloy with 33 per cent. of zinc, sometimes called the "Sibley Casting Alloy," because first made in the Sibley Laboratory at Cornell University, is extremely rigid, very slightly elastic, and breaks short like cast iron, with a fine-grained fracture. It

is not so resistant to shock as the alloys containing less zinc. Its specific gravity is only 3.8, and its volume is only 1.5 per cent. greater than the aluminium from which it is made. Its tensile strength is 24,000 pounds in sand castings and up to 40,000 pounds in chill castings, with no perceptible elongation or contraction of area. It works well, without requiring lubrication of the cutting tools. The large proportion of zinc in it makes it the cheapest of all the light aluminium alloys.

Besides these alloys with zinc alone, several casting alloys have been made containing both zinc and copper. Considerable amounts of alloys with 5 per cent. copper and 15 per cent. zinc, and as high as 27 per cent. zinc and 3 per cent. copper, have been made and used commercially. When cast under pressure they are stronger.

A commercial casting alloy being sold at present contains 15 per cent. of zinc and 5 per cent. of other hardeners, viz.: 2 per cent. tin, 2 per cent. copper, and one-half of 1 per cent. each of iron and manganese. It is recommended as making sharp, hard, strong castings.

RESUME.

According to the claims made, the magnesium alloys are the best all around of the light aluminium alloys, but they are expensive; the zinc alloys are the cheapest to make, and are equal in mechanical properties to very nearly the best alloys made with more expensive metals, and therefore promise to have, of all the light aluminium alloys, the largest sphere of usefulness.

TESTING OF BEARING METALS.

By G. H. Clamer.

To the operating department of railroads, to the constructors and operators of all manner of machinery with revolving parts, the question of bearings is of the highest importance. There is no other material of construction about which so much uncertainty exists, and no other material so worthy of consideration.

In the first place, it is generally conceded, and no doubt true, that the composition and structure of a bearing has much to do with causing or preventing so called "hot boxes." I say "causing," because segregations, hard spots, or whatever one may choose to call them, frequently are the source of irritation of the journal and its consequent results. I say "preventing," because a composition which is so constituted as to be of a yielding or plastic nature will often prevent the abrasion of the journal by conforming to its irregularities, etc.

Furthermore, the item of wear is a very material consideration in the operation of rolling stock and general machinery equipment, and a thorough study of the wearing properties of the various combinations of metals cannot fail to lead to a wonderful saving in bearing metal consumption.

The chief points to be considered in the study of such alloys are as follows:

1. Wear of bearing.
2. Wear of journal.
3. Friction.
4. Temperature of running.
5. Compressive strength.
6. Structure.

The first four of these tests can be made on a testing machine which is designed for the purpose. A great many machines have been designed, but most of them have been very unsatisfactory. The results obtained in this way are merely comparative, however, and cannot be compared to the actual service test, which is made under actual conditions. The best which the testing

machine can do is to give us a general knowledge of the qualifications of the alloy.

The wear tests are particularly important, and by comparison with a certain standard give the ratio of resistance to abrasion.

Time will not permit me to go into the details of the construction of machines, nor the method which I have adopted for carrying on tests of this kind, and I can only give some of the general conclusions arrived at in connection with the alloys which we have thus far examined.

Wear.—(1) Decreases with the decrease of tin in copper-tin alloy; (2) wear decreases with decrease of tin in copper-tin-lead alloy; (3) wear decreases with increase of lead in copper-lead alloy or copper-tin-lead alloy; (4) wear increases with increase of zinc in copper-tin-lead-zinc alloy; (5) wear increases with increase of antimony in lead-antimony alloy.

Wear on Journal.—In general, increases with decreased compressive strength, or, in other words, the hard metals, when running under normal conditions, cause less abrasion of the journal than soft metals. This, of course, does not refer to abnormal wear caused by actual gripment of the bearing surface.

Friction.—Theoretically, the friction is a feature depending on the kind of lubricant, and entirely independent of the kind of metal composing the bearing or the journal. Were it possible to have theoretically perfect surfaces, perfectly adjusted, the friction would be entirely fluid friction, or friction of fluid against solid. Actually, however, the bearing surfaces are of considerable consequence, even when running under normal conditions, and in general it may be noted that the softer the metals in contact the higher the coefficient of friction, and *vice versa;* but when the quality of the bearing is called into service to overcome aggravated conditions, for instance, when lubrication is interfered with, or foreign matter becomes interposed between the bearing surfaces, causing abnormal pressure, under such conditions it is necessary that the alloy have a certain yielding nature, in order to re-establish a large area for the distribution of pressure. It is for this reason that the softer metals will always give less trouble than harder metals, although the friction under normal conditions is higher with softer compositions.

Compressive Strength.—A test of the compressive strength gives a general knowledge of the pressure under which the metal will operate successfully: whether the alloy is brittle, and if it is sufficiently plastic to withstand a reasonable amount of ill use without becoming heated.

Structure.—An examination of the general structure of the alloy is quite important, as it shows defects, such as segregations, etc., which could reasonably be supposed to cause friction. It is with this in view that the specifications of the large railroad companies call for an examination of the fracture of at least one brass in each hundred.

Microscopically it has been shown by Charpy that a successful bearing alloy should consist of at least two structural constituents, one hard constituent to support the load, and one soft constituent to give it the plastic support. An investigation of this kind, therefore, tells us if the alloy possesses such an arrangement of its particles.

The importance attached to a careful study of bearing alloys will be apparent from the following figures:

There is in the service of railroads in the United States on 1,600,000 cars approximately 160,000,000 pounds and on 39,900 locomotives approximately 5,000,000 pounds, which at an average value of 13 cents per pound represent a money value of $21,450,000, and I should judge that the amount in service other than for rolling stock, for instance, on stationary engines, rolling mills, and machinery equipment of all kinds, would easily double this amount. It will be seen that a large part of the copper, tin, lead, antimony, and zinc consumption is for the manufacture of bearings.

An examination of the bearing metal specifications of the various large railroad systems will show a wide difference of opinion on the subject, and in view of the uncertainty existing, the large consumption, and the importance attached to the question, I recommend this as a suitable subject to be considered by this Society.

DISCUSSION.*

THE PRESIDENT.—Mr. Clamer is hardly just to himself, due to modesty. The use of lead in bearing metals, so far as our knowledge goes, was first made prominent by Mr. Dick, of London, the patentee of the so-called "S Bearing Metal," of the Phosphor-bronze Smelting Company. Standard phosphor-bronze contains about 10 per cent. of lead. Mr. Dick's patent stated that he had discovered that the addition of lead to a copper-tin alloy diminished the rate of wear of the bearing metal. Following this we made a large number of experiments at Altoona, trying to increase the amount of lead and to diminish the tin. We stopped at 15 per cent. of lead and 8 per cent. of tin. Mr. Clamer then took hold of the matter, and has actually succeeded in making a successful bearing metal with 30 per cent. of lead and only 5 per cent. of tin. A very ingenious feature of this metal is the means made use of to prevent the separation of the lead during cooling, namely, the addition of a small amount of nickel apparently raises the melting-point of the copper-tin alloy, so that it solidifies before the lead has had a chance to separate. I may add that the wear of bearing metals and car journals is no small item. Axles are usually removed from service, accidents aside, because the journals are worn too small to make it safe to run longer. We have no positive figures, but in general each journal of a car axle will wear off a pound of metal for about 75,000 miles. Bearing metals vary very greatly and no positive figures can be given, but each bearing usually loses not less than a pound of metal for 25,000 miles. As this metal costs from 14 to 16 cents per pound, and as there are eight bearings on a car, it is obvious that the rate of wear is a matter of no small import. The President.

G. H. CLAMER.—I should like to ask Professor Richards if magnalium is being reduced directly from the oxides? Mr. Clamer.

* Joint discussion of the two preceding papers, viz.: "The Light Aluminium Alloys," by J. W. Richards, and "The Testing of Bearing Metals," by G. W Clamer.

Mr. Richards. J. W. RICHARDS.—I think that the alloy with the zinc is possibly a good bearing metal. It seems to have the anti-friction qualities and the structure necessary for that. I know it has been used on spur wheels which have worn very well. Spur wheels made of this alloy working on steel wheels work almost noiselessly and it has been used for noiseless gearing with very good results. In a letter from Mr. MacAdam, of Brooklyn, who makes an aluminium alloy called Macadamite, he refused to tell me its composition, but added as a postscript that they had been using that alloy for machinery bearings, with very good results, so that I think there is a field for some of these light aluminium alloys as bearing metals.

Mr. Wickhorst. M. H. WICKHORST.—I want to call attention to certain features of ordinary phosphor-bronze for bearings, particularly in its relation to hot boxes. Most phosphor-bronze is made by melting the various metals and later introducing some phosphorus. The usual practice of manufacturers seems to be to wrap the phosphorus in wet paper, put it in a retort, as it is called—an inverted cup-shaped affair—and insert this into the metal, so that the phosphorus is melted and volatilized and, as it goes through the metal, is absorbed. There is one little subtle thing, however, that occurs here that has caused a whole lot of trouble on railroads and is not evident until it is worked out in some detail. When the phosphorus is thus volatilized and goes through the metal the moisture is at the same time volatilized. The oxygen of the moisture combines with the phosphorus, and goes off as white smoke, while the hydrogen remains dissolved in the molten metal. This hydrogen, if it is small in amount, does not do any particular harm; but when phosphor-bronze is manufactured in that way it is generally large enough in amount to afterward do considerable mischief. That is, the hydrogen acts a good deal as does air when dissolved in water; when water containing dissolved air is frozen, the air continues to go to the portion which is still liquid; finally it gets toward the centre, and when the water is finally all frozen the air is liberated as a gas, thus making the ice cakes porous. About the same thing occurs when bronze or metal is cast and solidifies in the mold in the regular process of casting, that is, the hydrogen remains in the metal when it is poured, and when the

bronze begins to solidify there is a coating around the outside of the mold, but afterward when the interior solidifies, then the gas goes off and generally rises toward the top of the casting, but its presence does not show on the outside. It is not seen until the casting is machined off, and then the effect is evident. A very interesting thing occurs during the process of casting: at first the metal pours very nicely; the gate begins to shrink down in a normal manner, but after two or three minutes, on looking at the gate, you will notice some lead-like beads starting to ooze out. The explanation is evidently that this bead-like material rises through the gate when the gas tries to liberate itself. I have analyzed these beads and found them to be largely a composition consisting of perhaps 20 per cent. tin, with copper and a little lead and phosphorus. The point is that these beads, while they look like lead in a molten condition, are as hard as bell-metal, and this segregation of hard spots undoubtedly goes on in the casting itself. Mr. Wickhorst

We have found by experience that such metal, when used in engine bearings, gives a great deal of trouble from heating. I first investigated this matter in connection with hot boxes, and I afterward worked out this explanation. In making our phosphor-bronze on the C. B. & Q. Railroad, instead of wrapping it in wet paper, we put it in a solution of blue vitriol, which coats the phosphorus with copper, so that it can be dried without danger of igniting. The cans of phosphorus are opened, the phosphorus is put into blue vitriol, and after standing a while it is put on blotting paper on netting, with a pan of water underneath. In that way phosphorus is introduced into the metal without at the same time introducing any dissolved hydrogen.

W. C. DU COMB, JR.—I should like to add to the President's remarks as to the use of lead as a bearing metal. I recently tested several bearing metals for friction under a load of 750 pounds per square inch, the oil being supplied by cotton waste; and also with a load of 250 pounds per square inch without oil. One of the specimens was claimed to be commercially pure lead, hardened by a process known only to the makers. The friction was extremely low, as might be expected, and although no compression tests were made, I understand from one who tested this metal in compression that, compared with ordinary lead, the compressive Mr. Du Comb.

Mr. Du Comb. strength was high. In pouring this metal it is necessary to use a clean ladle, and leave the bearing to harden for about two days.

This metal has been placed on the market and I thought it might be interesting to mention it, considering the fact that it is claimed to be a commercially pure lead bearing.

Mr. Richards. Mr. Richards.—If I may speak another word about this 25 per cent. zinc alloy, I would say that Mr. Troemner, of Philadelphia, has used it for making his balance beams for several years, and his statement is that this alloy, cast from the same pattern as bronze, is actually more rigid and stable than the bronze which it replaces. He was making a large five-foot beam once, and testing it; he was quite enthusiastic over the way it acted. When I asked, "Well, when you put the load on, what was the deflection?" He replied: "No deflection at all—if anything, it bent the other way."

Mr. Clamer. G. H. Clamer (by letter).—In further explanation of the 30 per cent. lead and 5 per cent. tin alloy, so kindly referred to by Dr. Dudley, I desire to add the following statements:

Some fifteen or twenty years ago our President conducted an elaborate series of tests for the Pennsylvania Railroad on the various copper, tin, and lead alloys then on the market. Copper and tin had been the standard-bearing metal heretofore, and, as pointed out by Dr. Dudley, the use of lead in bearing metals was first made prominent by Mr. Dick, of London, the patentee of the so-called "S. Bearing Metal." This metal seemed to be a decided advance over the copper and tin alloy heretofore used, but it was left to Dr. Dudley to actually demonstrate the value of lead in the copper and tin alloy, also to establish the relationship existing between the proportions of copper, tin, and lead contained in the same. A series of actual service tests were conducted by him, comparing the copper-tin and copper-tin-lead alloys in various proportions of the contained metals. The final conclusions drawn from these tests were as follows:

1. The alloys containing lead showed a decidedly less tendency to become heated.

2. The higher the proportion of lead and the lower the proportion of tin the less was the liability to become heated.

3. The rate of wear diminished with the diminution of tin. Mr. Clamer.

4. The rate of wear diminished with the increase of lead.

Furthermore, it was found that satisfactory alloys could not be made with under 8 per cent. tin or over 15 per cent. lead.

It was the valuable knowledge which these tests imparted which led us to experiment, in the endeavor to produce an alloy with higher lead and lower tin content, believing the above established facts would hold good with a further diminution of tin and increase of lead. Our efforts were rewarded, and, curiously enough, it was found that by decreasing the tin, larger amounts of lead could be withheld within the alloy, so that when the tin was diminished to 5 or 6 per cent., satisfactory castings could readily be made containing as high as 30 per cent. of lead. This is explained by reason of the fact that with low tin content the alloy contains but little or none of the copper-tin eutectic. The copper-tin eutectic, as perhaps all know, has a low melting-point in comparison with the balance of the alloy, and if this exists in other than small proportions, the greater part of the alloy must cool to about 930° before solidifying. This consumes considerable time, during which the still molten lead has abundant opportunity to segregate.

In the alloy as above specified containing copper 65 per cent., tin 5 per cent., lead 30 per cent., practically the entire bulk of the copper-tin constituent solidifying at an elevated temperature, mechanically envelops the lead and produces a homogeneous alloy. The content of nickel, as spoken of by Dr. Dudley, although benefiting to some extent the homogeneity of the alloy, is not an essential constituent, the object of the nickel being to enter into what eutectic there may be present, thus elevating its melting-point and causing quicker solidification of the alloy. This metal is being marketed under the name of "Plastic Bronze," and is manufactured by the Ajax Metal Company, Philadelphia. It has been on the market only a little over three years, but has come into very extended use for car, locomotive, and miscellaneous machinery bearings. This metal shows a rate of wear considerably lower than any other bronze on the market, and, at the same time, possesses exceptional anti-frictional qualities.

THE MASTER CAR BUILDERS' DROP-TESTING MACHINE AS INSTALLED AT PURDUE UNIVERSITY.

By William F. M. Goss.

Historical.—At its annual meeting in 1898, the Master Car Builders' Association appointed a committee to define fully the contour lines of M. C. B. couplers, and to propose specifications which might guide railroad companies in the purchase of new couplers. This committee consisted of Messrs. W. W. Atterbury, W. P. Appleyard, and W. S. Morris. The report which it presented at the next annual meeting dealt with the coupler question in a very comprehensive manner, recommending among other things that couplers offered to railways be subjected to a series of tests under a drop-testing machine. The committee not only defined the nature of these tests, but presented a design for a machine to be employed in carrying them out, and gave results of tests which had been secured by aid of an improvised machine to demonstrate the reasonableness of the specifications they proposed.* It was in the work of Mr. Atterbury's committee that the present M. C. B. drop-testing machine had its origin, and it is a high tribute to this body, that though the question of drop testing has been extensively studied since the date of its first report, the conceptions underlying the design of the machine which was then defined have not since been changed, As time went on, the original drop-testing machine, which had been located at Altoona, was improved in matters of detail, and it proved useful not only in tests of couplers, but in tests of draft-gears as well. Meantime, the chairmanship of the coupler committee had been transferred to Mr. R. N. Durborow, who in this manner became responsible for the later development of the machine.

The value of a drop-testing machine having become apparent, it was determined that the Association should provide itself with a perfected machine, and that said machine should not

* Master Car Builders' Association Proceedings, 1899, pp. 165 to 222.

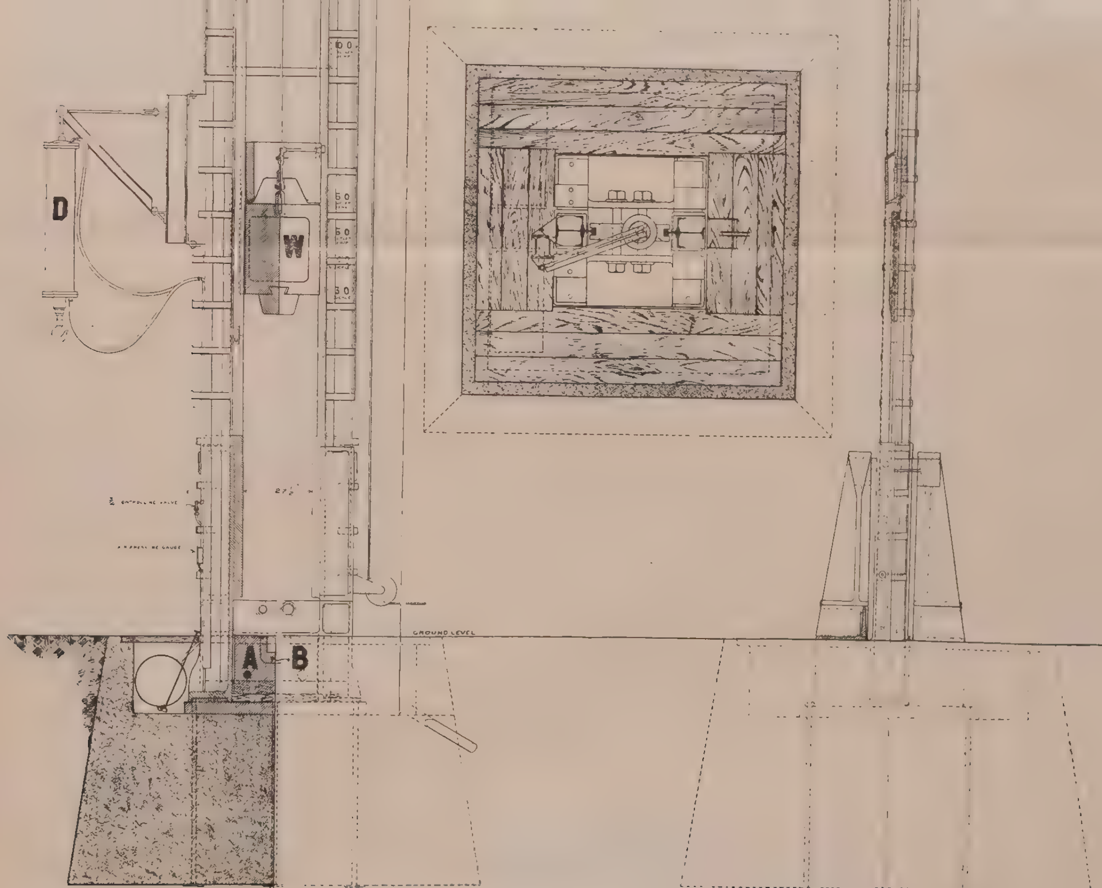
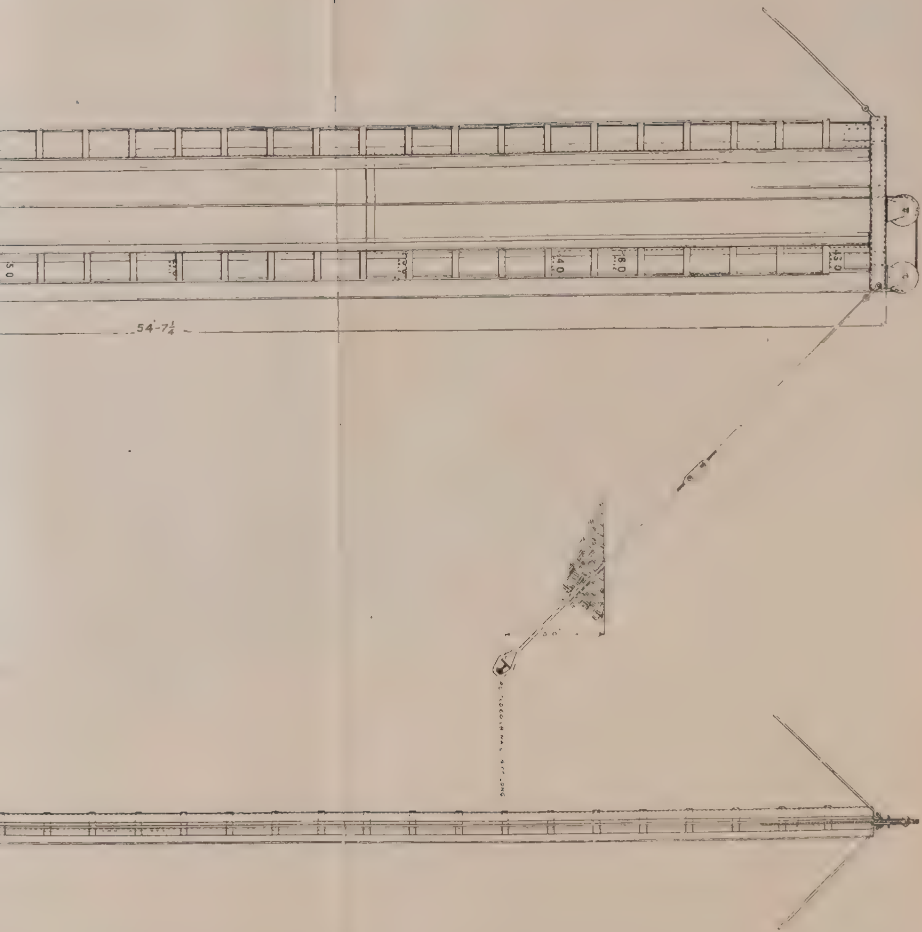

D
W
A
B
GROUND LEVEL

PLATE VIII.
PROC. AM. SOC. TEST. MATS.
VOLUME III.
GOSS ON M. C. B. DROP-TESTING MACHINE.



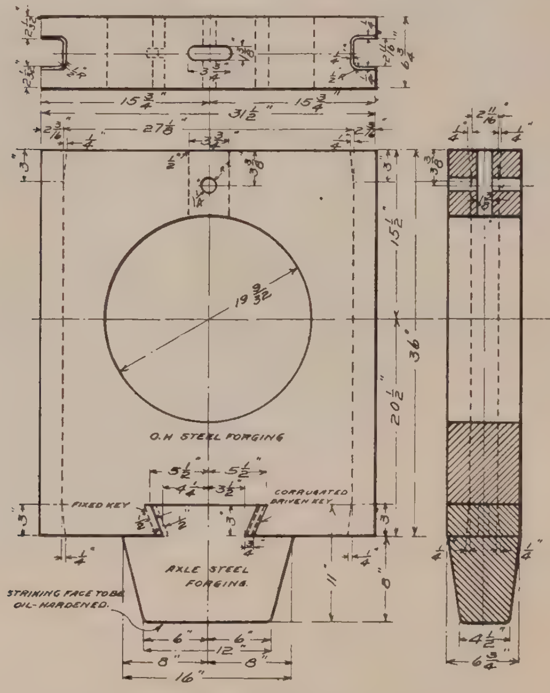
1.

be in the keeping of a railroad company, but should be established upon neutral ground. Since the air-brake testing rack and the brake-shoe testing machine of the Association had already been installed in the laboratories of Purdue University, the location for the proposed machine was easily chosen. All this was settled upon at the annual meeting of the Association in 1902, at which time the standing Committee on Tests of M. C. B. Couplers was authorized to carry out its recommendations as to certain modifications in the design of its testing machine, in order that it might be available for tests of draft-gears, axles, etc., and was authorized to accept the offer of the authorities of Purdue University to receive, install and maintain the machine. In accord with this action, the machine is now in the process of being erected at the University.

A Description of the Machine.—General elevations, sections and a plan are given on Plate VIII., Fig. 1. By these drawings it will be seen that the machine rests upon a foundation of concrete, above which it rises to a height of more than fifty-four feet. The anvil (A) is in the form of a rectangular casting weighing 17,000 pounds. For convenience in holding a coupler, as will hereafter be explained, it has in the middle an annealed steel insert (B). The anvil is carried by nests of coiled springs, which in turn bear upon a suitable foundation plate. The spring support of the anvil is intended to make the machine easily reproducible. It is assumed that the resisting qualities of an anvil thus supported will be the same whether the machine itself rests upon a rock foundation or upon soft soil.

The drop of the present machine, weighing 1640 pounds, is of forged steel and is shown in detail by Fig. 2. This weight meets the requirements of the M. C. B. specifications for coupler testing as well as those of the International Association for Testing Materials, with reference to axle testing, and is made to meet the requirements of the specifications of the last-named Association for rail testing by fitting disks to the cylindrical opening in such a manner as to increase its weight to 2000 pounds. The drop is handled by a wire cable served by a small reversible hoisting engine (not shown in the drawings). The traveller above the drop carries a tripping mechanism so arranged that when a stop is set the drop is released from any predetermined height.

The vertical guides are shown in enlarged section by Fig. 3. Each guide is made up of three rolled shapes, namely, a rail section, a channel, and an eye-beam, to which at intervals is added a curved brace to serve as a ladder. The height of the guides makes it necessary to have them guyed from the top as



DROP WEIGHT
NOTE:- WEIGHT OF FINISHED TOP WITH LINK AND SUSPENSION BOLT TO BE 1640 LBS

FIG. 2.

shown by Fig. 1. Their lower portions are reinforced by cast-steel housings, which are somewhat imperfectly shown by Fig. 1.

An air-hoist (D, Fig. 1) serves in handling accessory equipment and the materials to be tested. The hoist is carried by a double-hinged crane in such a manner that it may be swung

around to the center line of the machine from either side. This is best shown in the plan, Fig. 1.

Testing under the Drop.—To test either the guard-arm or the knuckle of a M. C. B. coupler under buffing strains, the shank of the coupler is dropped into the steel-lined pocket (B) of the anvil, and the body of the coupler is wedged into position under the drop by means of steel liners supplied for that purpose. Thus prepared, the M. C. B. specifications require that the couplers shall withstand three blows from a height of five feet and three blows from a height of ten feet, delivered either upon the closed knuckle or upon the guard-arm, without producing distortion beyond stated limits.

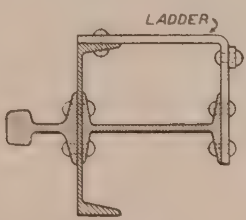


FIG. 3.

A tension ("jerk") test of couplers involves additional equipment, as shown upon a large scale by Fig. 4. In this case the coupler is fitted to a suitable yoke (F) which in turn is carried by springs performing the same function on the machine that is performed by the draft rigging on a car, the whole being suspended from a cross-girder surmounting two cast-steel columns. In the original machine two couplers were employed in this test, a suitably formed equalizer (E) extending between the couplers and receiving the blow from the drop. The left-hand elevation (Fig. 1) shows the columns on either side of the machine necessary to carry the two couplers referred to. In the present machine, however, the necessity for using two couplers has been avoided by having one end of the equalizer carried by a support (Fig. 4), beneath which are springs of the same character with those which carry the yoke on the other side. It is believed that in this manner the jerk test of couplers has been simplified and that for comparative purposes its value has not been diminished. The yoke F

is designed to receive coupler shanks of different dimensions by an opening sufficiently large to admit filling pieces, designed for the several different-sized shanks.

Draft-gears for test under the drop are fitted to short lengths of draft sills, the ends of which may rest directly upon the anvil of the machine. In the place of the usual yoke and coupler,

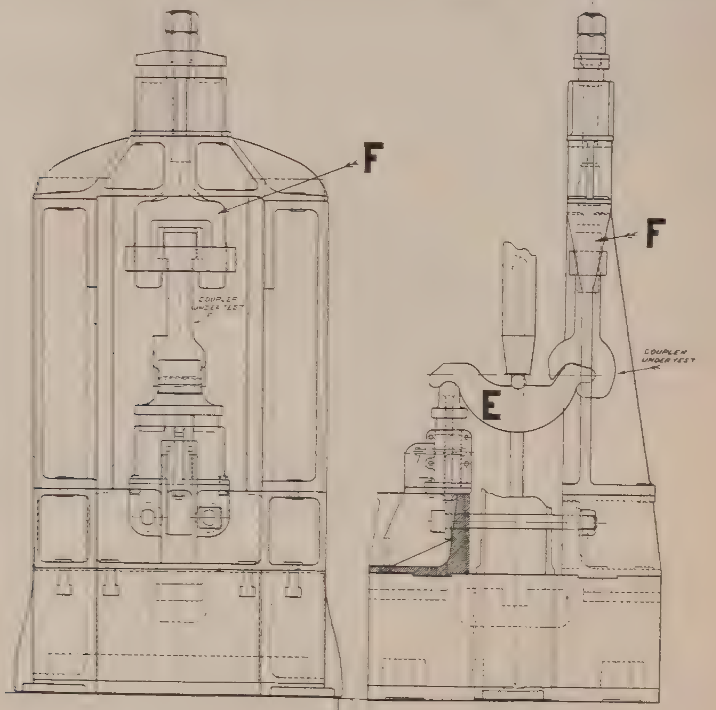


FIG. 4.

dummy construction is employed which will give a shank reaching out between the draft sills in such a manner as to receive the blow of the drop. Tension tests of draft gears by use of this machine are not contemplated.

For axle testing there are provided two supports which may be placed upon the anvil on either side of the center line of the

machine to receive the axle, which, when thus placed, may receive blows from the drop in the middle of its length.

Similar equipment serves in rail testing.

Research.—The Master Car Builders' drop-testing machine has been brought into existence to serve chiefly in routine work arising under certain specifications of the Association. There is, however, no reason why it may not also serve in work of engineering research. In view of the important studies of a highly scientific character concerning the behavior of constructive materials under impact, which have already been made by members of this Association by the aid of lighter machines, it is but reasonable to expect that a heavy, well-designed drop such as has been described will serve in extending the limits of such inquiries. In so far as the machine may serve such purposes it will fill an ever-increasing field of usefulness.

STREMMATOGRAPH TESTS OF UNIT FIBER STRAINS AND THEIR DISTRIBUTION IN THE BASE OF RAILS UNDER MOVING LOCOMOTIVES, CARS AND TRAINS.

By P. H. Dudley.

The large unit fiber stresses which occur in rails to carry their loads show that the entire permanent way for our best steam railroads is flexible and elastic by construction. The rails, cross-ties, and ballast resting upon a compressible, elastic, or plastic subgrade are forced down by the moving loads and generated forces of the locomotives and cars as they run over the track until the total resistance equals the effects of the superimposed loads. The rails and cross-ties are depressed by the wheel loads in the ballast from $\frac{1}{8}$ to $\frac{1}{4}$ of an inch under the present heavy locomotives and cars. The compression of the ballast and subgrade forms one-third to one-fifth of the total amount of the temporary subsidence of the rail. The subgrade is affected to a depth of 12 to 20 feet, according to its material, construction, and stability. There is a characteristic "general depression" of the rails, cross-ties, ballast, and subgrade produced by each type of locomotive or car to carry and distribute the loads with specific deflections in the rails under the wheel contacts.

The structure of the permanent way is, by design and construction, the mechanism to support the moving locomotives and cars and reduce their wheel-load intensities to those the ballast and subgrade can absorb without rapid deformation. It is restricted in depth and weight, and, from its flexibility and elasticity when unloaded, is a floating mechanism held in surface or not by the ballast resting on the compressible subgrade.

The trackman's surface of the rail is its normal position only when unloaded. It is forced down by the moving superimposed loads of the locomotive and cars to its lower loaded position in the "general depression" for the necessary conjoint support of the subgrade to carry the weights. The loads are transmitted and distributed through the wheel contacts and produce specific unit fiber strains under them in the rails.

A part of the superimposed loads of the locomotives and cars rolling over the superstructure is required to overcome the looseness, flexibility, and elasticity of the permanent way affected. Consequently the surface to which the rails will conform is an equilibrium of the acting and opposing forces in the general depression.

To maintain the track and keep it in condition the trackman must rely upon its surface as it appears when unloaded. It is true that he notices the lowering of the surface to the "general depression" when the locomotives and cars roll over the line. It becomes necessary to do the surfacing, tamping the ties, and aligning when the track is unloaded.

The task of tamping evenly sixteen to eighteen cross-ties per 30 feet rail, so that each deflects uniformly under the wheels is greater than is usually considered. He must judge of what the requisite stability of his track is in its general depression, to carry the trains, by its surface when unloaded. He must be able to determine closely the uniform tamping of his entire track from the surface of the rail as he looks over it with his eye.

The intelligent trackman not only knows that the surface of the rails and cross-ties is depressed, but that the ballast and subgrade are subject to movements under the moving loads of the trains. He must estimate the stability of his track as a structure for all conditions of weather. When it is comparatively dry the subgrade is firmer and the displacements under moving locomotives are less than when it is wet. He notices that when the drainage-line is comparatively near the surface of the rail he is obliged to expend more labor in maintaining the surface of his track than where it is some feet lower. He is compelled to do more work in the cuts than on the fills, as a rule, to maintain the surface. He learns from experience that more labor is required to maintain the shoulder rails of the outside tracks than the interior rails in double and four-track railroads.

The trackman finds by experience that as the stiffness of the rail section increases, and the efficiency of the joints, he can maintain a better "condition of track" than was possible upon light rails. The comparative reduction per mile in undulation from the 4½-inch 65-pound rails has been practically on an average from

8 feet to 2 feet on the $5\frac{1}{8}$-inch 80-pound rails. As the stiffness of the rails has increased, the axle loads and the total weight of the locomotives have been augmented in a greater ratio. The axle loads have been more than doubled, while the total weight of the locomotive has been increased for passenger service 60 to 70 per cent. Faster trains have been run, and the expenditure of the tractive effort of the locomotives has been more than doubled. Even with all the increase of the service, the trackman is able to maintain a better surface and a smoother track with the stiffer 80-pound rails with less labor than was possible with the $4\frac{1}{2}$-inch 65-pound rails. The mechanical element of stiffness between the two sections is 70 per cent. greater for the 80-pound, which with the locomotives has practically doubled the combined stability between them and the permanent way.

The loading of the rails in the general depression is not alike for the passage of two locomotives or cars. The flexibility and elasticity of the superstructure are in action, so that a uniform loading for each wheel is not secured. The static loads upon the forward truck wheels or upon the driving wheels do not produce corresponding unit fiber strains in the rails. In the depression of the rail from its unloaded to its loaded position, the truck wheels, in taking up the looseness of the track, produce proportionately greater strains than the heavier loads of the driving wheels. The rail in the general depression under the driving wheels is in better position to carry heavy loads than under the forward truck wheel. The looseness incident to the construction of the track has been reduced, and the driving wheels are running upon a portion of the rail which has been restrained efficiently and impressed firmly to the cross-ties, ballast, and subgrade, and retained by the following trailing and tender wheels.

The tabulations of the stremmatograph tests of the unit fiber strains in the rails, of the limited compressions preceding the pilot wheel of the locomotive, or following the rear wheel of the locomotive or train, indicate that the rails are deflected from the unloaded to the loaded position before the maximum unit fiber strains are produced under the wheel loads.

In our present tracks the rail section acts as a continuous girder and resolves the forces due to the moving wheel loads into

horizontal components of strain in the base and head of the rails, which is partly continued through the splice bars from one rail to the next to carry and distribute the wheel loads. The web of the rail also carries shearing strains at the points of flexure. In the section of the rail the neutral surface is neither elongated nor shortened by the deflections in the resolution of the components of a strain. In the head of the rail immediately under the wheel contact the metal is in compressive strain above the neutral surface, while below the metal is in tensile strain. A strain of one character above or below the neutral surface is balanced by an opposite one in the section.

The examination of a stremmatograph record of the unit fiber strains in the rails shows that they are a series of alternating strains of tension and compression as the wheel loads and their spacing move over that particular portion of the rail.

The problems in reference to the strains in rails and their distribution under moving locomotives and cars are so complicated by the looseness of the superstructure and the imperfect elasticity of the road-bed that they cannot be expected to yield to complete mathematical analysis, as is the case for bridge members. The rails are loose under the spikes in the cross-ties, and decided deflections and bending take place under the loads before the rails are impressed firmly upon the cross-ties and the latter in the ballast. The entire superstructure is an elastic mechanism in the ballast, and is not attached rigidly to the road-bed. Its weight and friction in the ballast are the only elements to hold it in connection with the road-bed, except it is loaded by the train and receives conjoint support from the ballast and subgrade. This permits and causes decided undulating movements and depressions in it before receiving efficient support from the road-bed. Then when the superstructure is depressed upon the ballast the subgrade is compressed, and decided movements take place in it, according to the material of which it is composed.

With the introduction of stiffer rails into the tracks and the high standards of smoothness which have been secured by reducing the looseness of the superstructure and its flexibility to a small amount, it is not yet a limited structure, like a bridge, in which the strains in the members may be traced, analyzed, and calcu-

lated. Our knowledge of the actual strains and their distribution in the rails is restricted to a few measurements. Extensive experiments have been made of the deflection of rails, and attempts to calculate what their unit fiber strains were under moving trains. While these were aided by comprehensive theoretical knowledge of the elasticity of metals, there was no way of confirming the correctness of the calculations, and the distribution of the stresses under the wheel base of the locomotive or cars was not traced. Such experiments have not led to what occurs actually in the distribution of the stresses under moving locomotives and cars, important knowledge to be ascertained for reducing and limiting the stresses.

It has been known by those conversant with the track that in the light rails which were in service ten and twenty years ago, from the permanent sets which they had taken, that at times the strains in the rails exceeded the elastic limits of the metal. They have been measured now, and found to be fully as high as was indicated by those which had taken permanent sets, and are higher than would be permissible in bridge members. While safety is the paramount question in either the bridge or rails, the conditions of service are so dissimilar that the same rules as to factors of safety do not apply. The bridge must support itself and the imposed load for several seconds, while the rail is supported and distributes infrequent driving wheel loads of great intensity of strain for a small fraction only of a second, and instantly relieved by one of an opposite character. These can be repeated a few times daily, and the rails not break after years of service. In the bridge the strains lasting for several seconds under the moving locomotives and trains must be limited to higher factors of safety than are required in rails. These have been ascertained from ample experience, and, as the stresses in the different members can be calculated, the construction of bridges is a matter now well understood.

Tracks of light rails may be strong in the sense of barely supporting the traffic, but the transmission of the wheel loads would be concentrated on each cross-tie, instead of being reduced and distributed.

Tracks of heavier rails would be safer and more efficient,

but still uneven and not capable of producing the requisite standards of smoothness for the traffic.

Tracks must be made of strong and stiff rails to secure the requisite standards of smoothness and distribution of the wheel loads required now for the present traffic.

The rails as sections and the physical properties of the metal should be capable of sustaining large unit fiber stresses without taking sets from deformations incident to service.

The stremmatograph was designed to determine the actual unit fiber strains in rails and their distribution under moving locomotives, cars and trains. It must be, by theory and construction, an instrument of precision, and, owing to the character of the unit fiber strains which take place in the rail, able to segregate the portion of it under which a test is to be made. The instrument must be capable of recording any extension of the metal due to its elasticity of tension or compression, with precision, in the length segregated, and, incidentally, as soon as the strain of one character is reversed, to record its opposite or absence in the same portion of the rail.

One of the important functions of the stremmatograph is to record autographically, on a phosphor-bronze slide, the distribution of the unit fiber strains in the base of the rail under the wheel base of the locomotive or car.

Subsequently, by the microscope, the ordinates of the strains can be measured, which will show whether the curve was continuous or discontinuous for the entire wheel base of the passing locomotive or car.

STREMMATOGRAPH TESTS.

The tabulations of Tests Nos. 257 and 271 are from the series of precision made to ascertain the distribution of stresses under the moving locomotives. Comparative tests for this purpose, made at different places, all agree as to the total stresses under the eight-wheel type of locomotives, with rigid trucks, within one-half of 1 per cent.; the total stresses for the same locomotive on the different dates compared also within one-half of 1 per cent. in total amounts. In Test No. 257 the forward truck wheel pro-

duced the greatest tension, while in the following test, December 30th, it was the rear truck wheel. The position of the counter weights, however, in passing over the stremmatograph, were different on the two days.

Locomotive No. 870 is of the eight-wheel type, and in the forward and backward stroke there is a slight movement of the front of the engine, due to the application of steam to the driving wheels. In the forward stroke the tendency is to pull down the front of the engine slightly over its center of gravity, while in the backward stroke the tendency is to raise it on the springs. These effects will load the truck as it passes over the stremmatograph in a different manner and affect the unit fiber strains. The compression in front of the truck wheel in Test No. 257 was 709 pounds, and the tension under the wheel 13,463 pounds. On December 30th, in Test No. 271, the compression in front of the truck wheel was 1653 pounds, and under the truck wheel the tension was 8976 pounds. In Test No. 257 the depression of the rail from its normal surface to the loaded position was by a long flexure, the wave preceding the pilot wheel being slight. This was a characteristic of eight tests out of eleven on the same date. The front truck wheel was reducing most of the looseness of the superstructure. In Test No. 271, on December 30th, both truck wheels were reducing the looseness, the wave in front of the pilot wheel being more decided than for the tests on the 23d instant. The thermal stresses in the rails on the two dates were not identical, as the variations in temperature show, and would have some influence in the modification of the depression of the rail from its higher, unloaded surface to that of the loaded condition in the "general depression." With the thermal stress of tension in the rails in the falling temperatures before the ends render in the splice bars, the looseness of the superstructure becomes less, and increases in rising temperatures when the thermal stress changes to compression before the rails render in the splice bars, due to expansion.*

* Nearly all rails break under the locomotives, during the decided falls in temperature, before the rail ends have rendered in the splice bars. Loosening some of the bolts in the autumn and readjusting the rails relieve them of tension, and has reduced the percentage of broken rails.

The small compression stresses in front of the truck wheels show that in lowering from the unloaded to the loaded position they are moderate, as a long portion of the rail is gradually depressed. Under the specific deflections in the "general depression" the stresses of tension, and particularly those of compression, increase. It will be noticed that the compression between the rear truck wheel and front driver in Test No. 257 was 3779 pounds, and in Test No. 271 4252 pounds. These compression stresses are not large for a $5\frac{1}{8}$-inch 80-pound rail, and indicate that the track was in excellent condition. The relief of the strain in the rail in the forward truck wheel in Test No. 257 is unusual.

The only stresses which are alike in the two tests were those under the front drivers. The tension was 26,926 pounds of unit fiber stress, which is not large for rails, though three times that which is considered permissible in bridge members, where the ultimate strength of the steel is only from 58,000 to 65,000 pounds, but little in excess of the elastic limits of the steel in the rails under test.

The stresses due to the tender become a part of those for the engine in holding and continuing the "general depression" of the rail for the driving wheels.

The drawbar-pull of the engine is continued and transmitted by the tender to the train. This becomes an important factor in distributing the stresses of the engine incident to its load for adhesion and the effect of its expended tractive effort to a longer portion of the track than that occupied by the driving-wheel base.

The increase in the stresses of the engine, due to its expended tractive effort, in the eight-wheel type is 15 to 30 per cent., according to the work performed. At this location the light engine would produce a total stress in the base of one rail of 108,000 to 110,000 pounds. The greatest total amount for the tests of the day, December 23d, Test No. 258, was 154,620 pounds, locomotive No. 934, same type and class as No. 870, drawing the fast mail, 13 cars, speed 48 miles per hour. Under the front driver the unit fiber stress was 37,082 pounds.* Larger unit fiber stresses than those given are frequent.

* This unit fiber stress was produced by a bending moment of 422,734 pounds.

In the first column of the tabulations of the tests are given the unit fiber stresses in the base of one rail, both of compression and tension. In the second column the total is given for the wheel base of the trucks and drivers of the engine, as well as for the tender and cars. In the third column, the unit fiber stresses per wheel base of the engine and tender. In the fourth column, the total stresses for the entire locomotive or a car.

In comparing the results of two locomotives of the same or different types, the total stresses are used in each case, and in the series of tests of precision for the determination of the distribution of the stresses under locomotives, only those were used in which the conditions were practically alike. This has occupied several years of time to reduce and repeat the tests, to secure total results agreeing within less than one-half of 1 per cent. with a class and type of engine. The results show that the distribution of the stresses under the locomotive as subdivided by the different subwheel bases should correspond closely to the total sum of the stresses as though distributed from the center of gravity of the entire locomotive. This has been found to be the case with the best designed locomotives in good condition with rigid front trucks. If we were able to determine precisely the stresses due to each wheel base the total should equal those obtained for the entire wheel base of the locomotives. As the subwheel bases pass over the stremmatograph, equalizing of the loads is occurring, so that a calculation would be required to show what the total should be for each wheel base. This prescribes considerable data which is not yet available in making such tests, and it becomes necessary, therefore, to compare the total stresses for the purpose of precision. That the sum of the effects of each wheel base should equal the stresses for the entire wheel base is in accordance with a well-known law of mechanics.

These tests of precision have been made to see how closely the locomotive as a machine and generator is capable of distributing and repeating its stresses upon the best track. Such results as have been acquired in the tests of precision can be obtained only on a high standard of track, with efficient joints, and locomotives in good condition.

In the fifth column is given the unit fiber stress per pound

of load in the base of one rail for the subwheel base of the drivers and trucks of engine, tender, or cars.

The figures are approximate only, yet they furnish instructive information in respect to the distribution of stresses under the supposed static wheel loading of the subwheel bases of the locomotive. When it is running, owing to the undulations in the track, also to movement of the wheels in their pedestals and the irregular application of steam to the driving wheels, it is impossible to expect results corresponding to its supposed static wheel loading. As stated, we have a flexible or elastic track, with looseness of the rails upon the cross-ties. This must first be reduced by the weight under the forward truck wheels, which at once modifies the effects of the calculated static wheel loads of the locomotive. If the tracks were inflexible, except for the strains in the rails to support the loads, then we should obtain unit fiber stresses corresponding to the supposed static wheel loading of the engine, except for the driving wheels.

It will be instructive to observe that the unit fiber stresses per pound of load in the rails under the forward trucks, carrying about one-half of the weight per axle of the driving wheels, are within one-fifth as much as those under the drivers, even with their added effect of the expended tractive effort. In other words, by a subdivision of the total load of the engine, a part may be used to stiffen and strengthen not only the superstructure but the subgrade, to carry and distribute the heavier driving wheel loads with less deformation than would be possible without the forward truck. In the ten and twelve-wheel types of engines for slow speeds, even more favorable results are secured. In some tests under twelve-wheel engines, at 15 miles per hour, under the forward truck the unit fiber stress per pound of load was one pound, which reduced to 0.7 of a pound for a total load of 140,000 pounds on the four pairs of driving wheels.

The forward truck under the front of the engine adds to its value and efficiency as a machine for locomotion, and is distinctly an American invention. It was designed first by Mr. John B. Jervis, in 1831, for an engine for the Mohawk & Hudson Railroad, and was under construction that year, and went into service in 1832. A plan for a similar truck engine was also sent to R. Stephen-

son & Co., New Castle-on-Tyne, England, for construction, and was received and run on the Schenectady & Saratoga Railroad in 1833. This was the inception and installation of the American theory and practice of subdividing the total load of the engine, and utilizing a portion of the weight by a forward leading and guiding truck to take up the looseness of the track and stiffen the portion of the rail occupied by the heavier loads of the driving wheels. The "general depression" of the rail started by the forward truck wheels is continued under the driving wheels to the rear portion of the rail held down by the following wheels of the tender. With this principle of distributing the loads of the locomotive, the greater weights carried upon the driving wheels do not produce a proportional increase of stress incident to the expenditure of their tractive effort and the load carried upon the driving wheels. The rail, instead of forming a deep depression under the driving wheels, is retained in a more level and uniform height in the general depression than would be the case without the assistance of the weight upon the forward truck. In extending the same principle to larger types of locomotives having more than two pairs of driving wheels the effect of the distribution of the increased load of the locomotives upon stiff rails has been rendered exceedingly advantageous, as already indicated.

Each type of locomotive produces on the track a distinct form of the general and specific deflections under its wheels. The decided reduction in unit fiber stresses and greater smoothness of the track, by the introduction of the stiffer rails, has made it possible within the last decade to draw heavy trains at high rates of speed. By the increased smoothness of the track incident to the stiffer rails and the higher maintenance possible, the locomotive in running over the track has been able to expend most of its power in overcoming train resistance without doing destructive work upon the track. If we examine the locomotive as a machine in the distribution of its loads by the different wheels of the wheel base, it will be seen how important it has been to increase the smoothness of the track so that the locomotive could run over it without generating destructive dynamic forces under each wheel. The center of gravity of the engine is nearly midway of its length, and, as a rule, below the center of its boiler shell. The center

of gravity of the tender will be midway of its length and about 5 to 6 feet from the top of the rails. The center of gravity of the locomotive will be vertically in line through the cab and below the center of gravity of the engine. With stiff rails and smooth track, with the force of the drawbar-pull between the engine and tender, the locomotive can distribute its load to the track nearly in accordance with its center of gravity. To do this completely, without the generation of destructive dynamic forces, each wheel should roll forward practically parallel with the surface of the rail, without undulations. The distribution of steam to the driving wheels will not be uniform, and some irregular motion will take place in their revolutions. The center of gravity of the engine should ride forward without undulations, also that of the tender. In such cases the center of gravity of the entire locomotive will move forward without much undulation. This high degree of perfection is seldom attained, though closely approximated.

If we examine the tabulation of the fiber stresses in the rail, we note that between the wheel contacts, as well as under the wheels, the rail is distributing its load by horizontal components of strains in the base and head of the rail. For the rail sections to perform completely the functions of a continuous girder, the joints of the rails must be able to continue the same functions as the rail section. It is necessary to support not only the rail ends, but prevent them from rising and also from separating or closing between the wheels as the locomotive moves over the track. Rails in which the ends were supported by chair-joints would not be capable of transmitting the horizontal components of strain from one rail to the next. With efficient splice bars bolted firmly, so that the rails will not render without a greater force than the strains imposed by the passing locomotive, then the bars are able to transmit, in a measure, the horizontal components of strain from one rail to the next; that is, they continue it between the wheels and under the wheel which is passing over the joint.

For the most efficient distribution of the total load of the locomotive the wheel base must have proper design, so that the wheel spacings are not excessive. It is noted often that the wheel spacing between the rear driving wheels and front truck wheels of the tender is so long that the rail is relieved nearly of

strain in the wheel spacing. In such conditions, which may be observed on light rails, the engine forms a general depression, and the following tender also another depression. These are both greater than would be the case were the "general depression" formed by the driving wheels continued to the wheels of the tender.

The general idea that the span of the bending rail is in accordance with the tie spacing is not confirmed. Owing to the looseness of the rails upon the cross-ties, the span of the bending rails is influenced by the wheel spacing of the locomotive in distributing its load.

As the stiffness of the rails has been increased the axle loads have doubled within the past decade. The distribution of heavy loads upon stiff rails can be made without undue injury to the track. With the increased axle load the intensity of the pressure between the wheel tread and the head of the rail is augmented. The only way to relieve this is by a slight increase in width of head, and provide for it with proper physical qualities in the metal.

NEW YORK CENTRAL AND HUDSON RIVER RAILROAD.

P. H. Dudley's Stremmatograph Tests, December 23, 1899.

No. 257. Track No. 1. Location, 6° curve 600 feet west of Mile Post No. 10.
Rail 5⅛ inch, 80 lbs. Moment of Inertia 28.5 4th Power inches.
Cross-ties. Length 8′. Width 9″. Thickness 6″. Wood Y. P. Weight 155 lbs.
No. 18 per 30 feet rail. Average weight of superstructure per yard 449 lbs.
Three-tie supported joints, 36 inch splice bars, Stone ballast.
Train No. 51, Empire State Express. No. of cars 4. Weight 430,000 lbs.
Locomotive No. 870. New weight 220,000 lbs. Speed 42 miles per hour. Temperature 40°.
The apparent mean extreme unit fiber stresses in the base of one rail were as follows in pounds:

				Per wheel base of			Per lb. of wheel base of
			Per wheel.	Drivers and trucks of engine, tender and cars.	Engine and tender.	Locomotive and cars.	Drivers and trucks of engine, tender and cars.
		Extra wave preceding truck wheel.					
		Compression in front of truck wheel	709				
Locomotive, Engine	Truck	o Tension under front truck wheel	13,463				
		Compression between front and rear truck wheel	709	23,857	……	……	1.072
		o Tension under rear truck wheel	7,086				
		Compression between truck wheel and front driver	3,779		83,024	……	1.369
	Drivers	⊙ Tension under front driver	26,926				
		Compression between drivers	4,252				
		⊙ Tension under rear driver	24,564	59,167			
		Compression between rear driver and front tender wheel	3,071			127,075	
Locomotive, Tender	F. T.	o Tension under front tender wheels	10,157				
		Compression between tender wheels front truck	0	20,904	……	……	0.931
		o Tension under rear tender wheel front truck	8,031				
		Compression between front and rear tender trucks	2,362		44,051		
	R. T.	o Tension under front tender wheel rear truck	8,976				
		Compression between wheels of rear tender truck	472	23,147	……	……	1.031
		o Tension under rear tender wheel	11,337				
		Compression between tender wheel and first car wheel	2,362				
First Car	Front Truck	o Tension under front wheel of first car	9,684				
		Compression between first and middle wheel	272				
		o Tension under middle wheel	12,764				
		Compression between middle and rear wheel	1,417	34,756	……	……	1.310
		o Tension under rear wheel	8,503				
		Compression back of wheel	945				
		Compression in center of wheel space	0				
		Compression in front of wheel of rear truck	2,362				
	Rear Truck	o Tension under front wheel of rear truck	9,920				
		Compression between front and middle wheels	1,181				
		o Tension under middle wheel	8,379	38,895	……	……	1.280
		Compression between middle and rear wheel	2,362				
		o Tension under rear wheel	8,976				
		Compression between trucks of first and second cars	709				

NEW YORK CENTRAL AND HUDSON RIVER RAILROAD.

P. H. Dudley's Stremmatograph Tests, December 30, 1899.

No. 271. Track No. 1. Location, 6° curve 600 feet west of Mile Post No. 10.
Rail 5⅛ inch, 80 lbs. Moment of Inertia 28.5 4th Power inches.
Cross-ties. Length 8′. Width 9″. Thickness 6″. Wood Y. P. Weight 155 lbs.
No. 18 per 30 feet rail. Average weight of superstructure per yard 449 lbs.
Three-tie supported joints, 36 inch splice bars, Stone ballast.
Train No. 51, Empire State Express. No. of cars 4. Weight 430,000 lbs.
Locomotive No. 870. Weight 220,000 lbs. Speed 44 miles per hour. Temperature 6°.
The apparent mean extreme unit fiber stresses in the base of one rail were as follows in pounds:

				Per wheel.	Per wheel base of: Drivers and trucks of engine, tender and cars.	Per wheel base of: Engine and tender.	Per wheel base of: Locomotive and cars.	Per lb. of wheel base of: Drivers and trucks of engine, tender and cars.
Locomotive	Engine		Extra wave preceding truck wheel.					
			Compression in front of truck wheel	1,653				
		Truck	o Tension under front truck wheel	8,976				
			Compression between front and rear truck wheel	709	24,093	....	....	1.083
			o Tension under rear truck wheel	10,629				
			Compression between truck wheel and front driver	4,252		79,835	....	1.249
		Driver	⊙ Tension under front driver	26,926				
			Compression between drivers	2,834				
			⊙ Tension under rear driver	22,675	55,742			
			Compression between rear driver and front tender wheel	2,362				
	Tender	F. T.	o Tension under front tender wheels	7,558			127,781	
			Compression between tender wheels, front truck	236	20,903	....	....	0.893
			o Tension under rear tender wheel front truck	11,101				
			Compression between front and rear tender trucks	1,653		47,948		
		R. T.	o Tension under front tender wheel rear truck	9,684				
			Compression between wheels of rear tender truck	1,653	27,043	....	....	1.159
			o Tension under rear tender wheel	13,699				
			Compression between tender wheel and first car wheel	2,362				
First Car		Front Truck	o Tension under front wheel of first car	9,684				
			Compression between first and middle wheel	2,362				
			o Tension under middle wheel	10,393				
			Compression between middle and rear wheel	0	31,887	....	....	1.200
			o Tension under rear wheel	8,031				
			Compression back of wheel	0				
			Compression in center of wheel space	472				
			Compression in front of wheel of rear truck	1,890				
		Rear Truck	o Tension under front wheel of rear truck	8,031				
			Compression between front and middle wheels	2,126				
			o Tension under middle wheel	12,046	38,619	....	....	1.310
			Compression between middle and rear wheel	236				
			o Tension under rear wheel	14,172				
			Compression between trucks of first and second cars	236				

NOTE.

From the unit fiber strains as measured by the stremmatograph, for a given section of rail, from its section modulus we can approximate the bending moment which produced the strain of tension. For the $5\frac{1}{8}$-inch 80-pound rail mentioned in Tests Nos. 257 and 271, the section modulus is 11.4. In either of the tests, the maximum tension under the front driver was 26,926 pounds, corresponding to a bending moment of 306,956 inch-pounds. The wheel effect produced also some compression either side of the wheel in distributing the load.

If the cross-ties in the ballast were inflexible supports, such large bending moments, and consequent unit fiber strains in the rail, could not occur. The cross-ties, ballast, and subgrade were depressed over 0.06 of an inch under the wheel, to produce the maximum bending moment in Tests Nos. 257 and 271.

The distribution of the load between the wheels is not uniform, and the ballast in the center of the wheel spacing was compressed less than one-third of that directly under the wheel.

Bending moments of 400,000 to 450,000 inch-pounds occur daily in the $5\frac{1}{8}$-inch 80-pound rails, and unless the elastic limits of the metal are high the rails are liable to take a set.

Engine No. 934, at the same place, in Test No. 258, produced a bending moment of 422,734 inch-pounds.

The 6-inch 100-pound rails can carry a bending moment of 500,000 to 600,000 inch-pounds without taking a set. Light rails cannot carry such large bending moments, and therefore must receive a greater support per cross-tie, from the reaction of the ballast and subgrade, the undulations in the rails being more decided.

Since the above paper was written a number of tests have been made on the depression of the ballast under the locomotives. The most decided depression takes place under the specific deflections of the wheels in the "General Depression." In some instances the ballast in the center of the wheel spacing under the locomotive was compressed only one-fourth to one-fifth of the amount directly under the wheels. This varies in different localities, owing to a greater or less percentage of moisture in the subgrade.

THE DETECTION OF THE FINISHING TEMPERATURES OF STEEL RAILS BY THE THERMO-MAGNETIC SELECTOR.

By Albert Sauveur and Jasper Whiting.

The following few paragraphs from a recent paper* by one of us will form a proper introduction to this paper:

"It is well known that when a piece of steel is allowed to cool undisturbedly from a high temperature, it crystallizes, and that the resulting crystals or grains as they are frequently called, are the larger, the higher the initial temperature and the slower the cooling. This was first forcibly stated by Professor Tschernoff in his masterly paper on 'The Manufacture of Steel and the Mode of Working It,' communicated to the Russian Technical Society in April and May, 1868.

"It is also well known that if steel be vigorously worked (rolled or forged) while it is cooling from a high temperature, crystallization is prevented, but as soon as work ceases crystallization sets in until a certain temperature is reached, which in the majority of cases is not far from 700° C., and below which there is no further growth of crystals."

We may, for convenience, call the range of temperature during which steel crystallizes, and which extends from the melting-point to this critical temperature, the crystallizing range.

It follows from the above considerations that in working steel, as is done in the manufacture of so many implements, from a high to a much lower temperature, crystallization is retarded—*i. e.*, is made up to cover a much shorter range of temperature, extending from the *finishing temperature* (*i. e.*, the temperature at which work ceases) to the critical temperature. The resulting structure will, therefore, be finer grained—*i. e.*, will be made up of smaller crystals—than if the metal had been allowed to cool *undisturbedly* from a higher temperature; the crystals will be the smaller the lower the finishing temperature.

It has been conclusively shown that the finer the structure—*i. e.*, the smaller the crystals—the more ductile will be the steel, and since ductility is always a very desirable property, whatever

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* Structure and Finishing Temperatures of Steel Rails, by Albert Sauveur. *Proceedings of the American Society for Testing Materials*, Vol. II., p. 79.

the intended use of the finished implement, we should so conduct our treatment of the metal as to confer upon it the finest possible structure. The importance of finishing steel implements at the proper temperature, therefore, need not be insisted upon. It is now appreciated by all enlightened metallurgists.

The manufacturers of steel rails have, more than any other producers of finished steel articles, given careful attention to the important influence of the finishing temperature upon the structure and the physical properties of their rails. In these days, when the tendency is to allow more and more carbon in rail steel, in order to lengthen the life of the rail, the importance of securing all the ductility possible from the heat treatment stands pre-eminently at the front.

It is quite certain that if a satisfactory means could be devised to ascertain whether or not rails are finished at the proper temperature, rail consumers would specify the application of such a test and would thereby obtain rails of a better and more uniform quality. It is well known to the readers of this paper that several methods have been proposed to this end, that they have been tried tentatively, but that none has proved satisfactory. Efforts have been made to determine the finishing temperature (1) by the use of pyrometers, (2) by the shrinkage of the rails after leaving the finishing rolls, and (3) by the examination of the microstructure of the rails. The use of pyrometers naturally suggested itself at first as the most promising means of accomplishing that purpose, but it was soon found that no pyrometric device existed which could be applied in a practical way to the detection of the temperature of quickly moving rails. The control of the finishing temperature by the amount of contraction which the rail undergoes in cooling from the finishing to the atmospheric temperature is open to serious objections; they have been discussed before this Society and need not be reviewed here. Finally, the micro test, although attractive and useful, can only be applied to a very small percentage of the rails manufactured, and this is its greatest weakness.

A truly practical and efficient method of preventing the rolling of coarsely crystalline rails should fulfil the following requirements: (1) it should be continuous in its working—*i. e.*,

it should test *every rail;* (2) its working should be automatic; (3) it should not interfere with the speed or simplicity of the mill operations, and (4) the cost of its installation, maintenance, and operation should not be excessive.

The method now to be briefly described appears to fulfil these requirements.

It is well known that when steel is heated to a high temperature it loses its magnetic properties—*i.e.*, it ceases to be attracted by a magnet. On cooling the metal remains non-magnetic until a certain critical temperature is reached, when it regains its magnetism quite abruptly. In the case of medium-high and of high-carbon steel this change in the magnetic properties occurs at the well-known point of recalescence, which also precisely marks the end of the crystallizing range. It is evident, therefore, that steel rails, in order to have a fine structure, should be magnetic when leaving the finishing rolls or should become magnetic shortly after leaving them, because this would indicate that they were finished but slightly, if at all, above the point of recalescence.

These considerations naturally suggest the application of a magnetic test to the control of finishing temperatures of steel implements, and this paper is merely a brief description of our efforts in this direction. Various methods of applying the magnetic test naturally come to mind. In order to be effective and practical, however, the mechanism should be automatic and actuated solely by the magnetic properties of the finished product. These automatic devices may be grouped into two classes :

1. The automatic separation of magnetic from non-magnetic rails, through the deflection of the magnetic rails, brought about (*a*) by the deflection of the magnetic rails themselves, due to the attractive influence of a magnet, or (*b*) by the motion of a suitable deflector placed in their path and which is controlled by the motion of a magnet, actuated in turn by the magnetic conditions of the rails. These two arrangements are indicated in a conventional manner in Figs. 1 and 2, respectively.* It

* Acknowledgment is made to the *Railroad Gazette* for the cuts used in this paper.

will be evident that the magnetic device instead of being placed in close proximity to the rolls may be located at some other point, near the hot saws, for instance.

2. The automatic stamping of magnetic rails to the exclusion of others, or *vice versa.*

This method appears to us to be the more practical of the two, and it will suffice for the purpose of this paper to describe only that arrangement which, after careful study of the problem involved, has seemed to us to be the most promising.

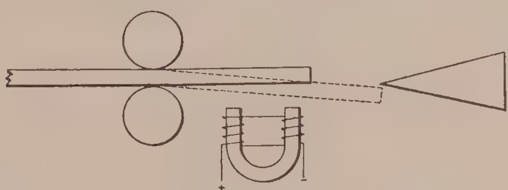


Fig. 1.

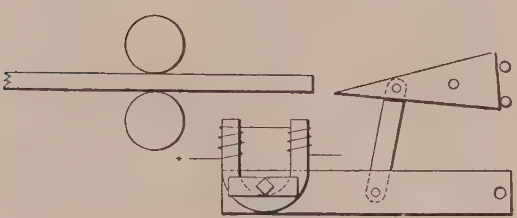


Fig. 2.

The device illustrated in Fig. 3 consists of a rail-stamping machine of the usual design, arranged to place in the runway from the hot saws. The rails pass over two rollers keyed on to steel shafts extended back to the frame of the machine. To the rear of the frame is attached a steel keeper and bridge piece. This keeper is supported on a pin in such a way that if the two steel shafts become magnetized, it will be attracted and drawn down against the ends of the shafts. The tendency to magnetic attraction is resisted by a spring which serves the purpose of drawing the keeper away from the ends of the magnet as soon as the shaft ends forming the magnet poles become so weak as

to have less influence on the keeper than the spring. The two solenoid spools are intended to be energized by means of an electric current, the connections of which are not shown. The action of the machine is as follows : When a rail which is cold enough to be magnetic passes over the two rollers it closes the air gap between the rollers, and by the closing of this air gap the magnetic flux which is passing through the steel shafts, due to the current flowing in the solenoid, is increased many times. It will be seen that by thus connecting the two steel shafts by means of a magnetic rail, a horseshoe magnet is formed with the poles at the rear of the machine. This increase in flux causes

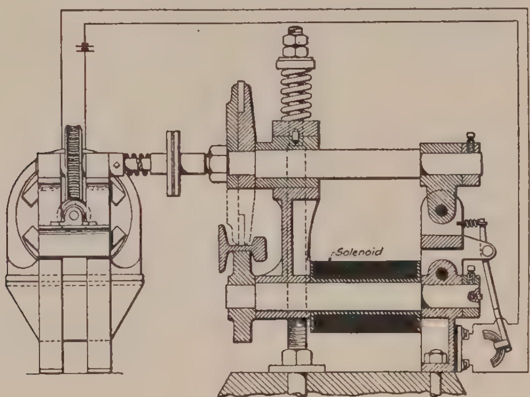


Fig. 3.

the keeper and bridge piece to be attracted, thus forming a complete magnetic circuit through the two steel shafts, the rail and the keeper. As soon as the keeper is attracted it closes the electric switch, which establishes a circuit through the electric motor, which in turn revolves the shaft carrying the stamp, thereby causing the stamping of the magnetic rail. The stamping mechanism is briefly as follows: The motor acting through the worm and gear revolves the shaft. The resulting movement of the die wheel brings the first character against the rail, after which the movement of the rail past the die wheel rotates the latter positively, until the last character passes out of engagement

with the rail. The purpose of the friction clutch is to provide for differences in the relative speeds of motor and rail, and to permit the rotation of the shaft to come wholly under the control of the rail after the die has been brought into engagement with the rail through the medium of the friction clutch. As soon as the rail leaves the rollers the spring returns the armature to normal position, thus opening the circuit and stopping the motor. Rails which are finished too hot to be magnetic pass through without being stamped.

DISCUSSION.

Mr. Mathews. JOHN A. MATHEWS.—I should think it far more important to determine and to control the temperature before the rail is given the last pass. This apparatus would hardly do that. It would be better to determine the heat before the finishing pass, rather than that its return to the magnetic condition be detected at an indefinite time after finishing.

The President. THE PRESIDENT.—I should like to ask Professor Sauveur whether the difference in carbon content would make any difference in the amount of magnetism evolved according to the temperature?

Mr. Sauveur. ALBERT SAUVEUR.—I suppose it makes a difference; but I take it that there would be enough magnetism left in the rail to set the apparatus working.

Mr. Job. ROBERT JOB.—Under the ordinary working conditions at the mill, a rail would go through the last pass before the critical temperature had been reached, and since the magnetic action would begin at the critical point, the instrument would necessarily be placed at a distance beyond the rolls.

Mr. Sauveur. MR. SAUVEUR.—I think Mr. Job is quite right. I do not know just where the apparatus had better be placed: immediately after the finishing roll or at some distance from the same.

Mr. Campbell. WILLIAM CAMPBELL.—I understood Professor Sauveur to say that the magnetic properties of the rail change at the recalescence point. Is it not a fact that the magnetic properties change at the point $AR_{3,2}$, not AR_1?

Mr. Sauveur. MR. SAUVEUR.—I should like to call Dr. Campbell's attention to the fact that we are dealing now with relatively high carbon steel and that the critical point $AR_{3,2}$ which marks the change in the magnetic properties is practically the same as the recalescent point. It becomes merged with it as $AR_{3,2,1}$, so that the recalescence point also marks the change in magnetic properties.

Mr. Richards. J. W. RICHARDS.—It strikes me that the apparatus of Mr. Sauveur would simply divide the rails into those which were finished below and above a certain temperature; but how far above

the prescribed temperature they were finished would not be indicated. I hope the time will come when there will be an automatic or an easily applied pyrometer which can be applied to the rail before the last pass and by which the workmen, by looking at an indicator, can see at once its temperature. The rail may then be held until the correct finishing temperature is reached and the last pass made at a certain fixed temperature. I think that would be quite a possible arrangement with a thermo-electric pyrometer, which should touch the rail just before the last pass and give indications on a large dial, the rails being held until the temperature is just right. Mr. Richards.

MR. MATHEWS.—It would seem to me that the actual temperature before the finishing pass might be readily determined by some such instrument as the Morse heat gage. This instrument has been very successfully used in the practical hardening of steel. The principle is simple. There is an incandescent lamp in a tube through which one looks at the hot object. The color of this filament depends upon the current used, and this is controlled by a rheostat and measured by a milammeter. The scale of the milammeter is calibrated to give degrees of temperature directly. When, in using the instrument, the filament seems to disappear we know that the object and the filament are of the same temperature. If the filament, as compared with the object, appears dark the object is hotter; if the filament appears relatively bright the object is at the lower heat. The inventor of this heat gage is Mr. Morse, of the Morse Chain Company, Trumansburg, N. Y. In his case necessity was the mother of invention, for in making their well-known and nearly frictionless chain, it was of the utmost importance that all the links be hardened at identical temperatures. In solving this problem this apparatus was invented. It is thoroughly practical to do hardening within limits of 10° C. The instrument itself is not expensive, but the installation of it is, particularly if exclusive rights for any one industry or use are obtained. Each lamp used in the heat gage is carefully calibrated by means of either the thermo-couple or the air thermometer. Mr. Mathews.

G. H. CLAMER.—I can testify to the accuracy of the Morse heat gage. I was chairman of the committee to examine that Mr. Clamer.

Mr. Clamer. instrument for the Franklin Institute, and we investigated it very carefully. Determinations can be made, as Mr. Morse claims, within about five to ten degrees. The apparatus is extremely simple. The current passing through the lamp can be regulated, thus bringing the color of the filament to correspond to the desired temperature. By bringing the rail underneath it at the point where the filament disappears, or apparently becomes a part of the steel, they can be said to be of equal temperature. The filament is in the direct rays of light coming from the piece the temperature of which it is desired to determine, and not to one side, as with other optical pyrometers. I think the apparatus should have a wide field of usefulness.

Mr. Mathews. MR. MATHEWS.—The apparatus can be made portable or stationary. You can carry the lamp around with you from place to place in any kind of mill by the use of storage batteries. The eye is as readily trained to using this gauge as it is to using the saccharimeter or other apparatus of that sort. It seems to me one could readily determine the temperature of the rail before the last pass by using such a device.

Mr. Sauveur. MR. SAUVEUR.—I think there is a mistaken idea about the results that can be obtained by keeping a rail before the last pass, as was shown in another discussion before this Society. If you find that the rail is too hot before it has gone through the last pass and detain it a while, that rail is crystallizing and will after the finishing pass have a coarse structure. The finishing pass is not enough to break it.

Mr. Christie. JAMES CHRISTIE.—There is one difficulty about the pyrometer that cannot be easily overcome in practice. The outer surface cools more rapidly than the interior of the bar, and in the case of larger sections the difference may be very considerable. No matter how accurate the pyrometer readings may be, they indicate only the temperatures at the surface of the bar.

Mr. Mathews. MR. MATHEWS.—The same argument applies in regard to the magnetic properties: the outside of the rail becomes magnetic before the inside. There is a gradual magnetic transformation proceeding from outside to inside as the steel cools off. Thus the same thing applies whether we determine the temperature directly or the return to the magnetic state, which depends on the tem-

perature. In one method you ascertain how much the steel is above the finishing temperature; in the other you really have to wait until it passes the critical point and becomes magnetic and use this interval of time as a guide to right practice. I do not say that this cannot be done, but the first method appeals to me more strongly. Mr. Mathews.

MR. SAUVEUR.—It simply means that we shall have to decide where to place this magnetic selector; whether we will place it very near or at a little distance from the finishing rolls. At any rate it gives us a means of separating in an automatic manner those rails that are finished above a certain temperature from those finished below that temperature; and it is only a question of locating properly the instruments in order to obtain rails with a sufficiently close structure. Mr Sauveur.

A DIRECT READING APPARATUS FOR TESTING TRANSFORMER IRON.

By J. Walter Esterline.

Sheet steel is now universally used for making the cores of transformers, generators, and motors, and in those parts of the magnetic circuit in which the magnetic flux has a cyclic variation in order to reduce the losses of energy which act to lower the operating efficiency of the device.

In sheet-metal cores the greater of the two losses is due to magnetic hysteresis, which is the dissipation of energy in reversing the flux passing through the metal. When a mass of iron is magnetized in a given direction, upon the removal of the magnetizing force it will tend to remain so magnetized, and the removal of the flux which remains, by the application of a reversed magnetizing force, requires the expenditure of energy which appears as heat.

The losses due to the phenomenon of hysteresis or magnetic inertia depend upon the rate at which the alternations of flux direction take place, the range through which the iron is magnetized and the quality of the metal; the soft, well-annealed irons having a much lower hysteretic loss than hardened iron.

The second loss is due to eddy currents, which are idle currents of electricity traversing the iron in paths at right angles to the direction of the magnetic lines of force. These currents are produced by the variations of magnetic flux in the iron, and are dependent in magnitude upon the magnetic density, the frequency of the flux reversals and the degree of lamination—*i. e.*, the thickness of the sheets of iron and the insulation provided between adjacent sheets. The eddy current losses are greatly reduced by laminating the cores parallel to the lines of force, as each space between laminæ then offers a barrier to the flow of the electric current.

Since these magnetic losses occur at all times when the apparatus is in operation, independent of the load upon the machine, it is highly desirable to reduce them to the lowest possible value, to obtain more efficient operation and better thermal conditions.

The best manner in which to determine the quality of magnetic material and its fitness for use in electric construction, is to make frequent tests of samples selected from the stock. A method of magnetic testing, to meet with favor, should possess the following characteristics :

1. Samples should be easily, quickly, and inexpensively prepared.

2. Method should be rapid, and yet give high relative accuracy and fair absolute accuracy.

3. Apparatus should be simple, and not be affected by vibrations, magnetic fields, etc.

4. Instrument should preferably be direct reading, requiring little or no calculation in deducing results.

5. Samples should conform as nearly as possible in form and shape to the stampings to be used, especially if high absolute accuracy is desired.

The apparatus which forms the subject of this paper was designed with a view of embodying as nearly as possible all the features which have just been set forth. It is well known that when an alternating current is used to magnetize a circuit, the power expended in the circuit will be that necessary to overcome the ohmic resistance of the conductor, and that dissipated due to the magnetic losses. Hence, a wattmeter placed in the circuit will indicate the combined resistance and magnetic losses.

The apparatus consists of two non-conducting shells, each containing one-half of a magnetizing coil, so designed that the two forms may be readily taken apart and placed together again. The two ends of each turn of wire in the upper half of the encasement fit accurately into mercury cups, which form the terminals of the other half of the same coil, so that when the upper half has been removed and replaced each convolution is restored, and the current finds continuous path throughout the winding.

As shown in Fig. 1, the original design was made to use a sample in the form of a concentric disc, which readily fits into the space between the outer and inner parts of the winding. It should be noted in this connection that the general form of the apparatus can be changed to accommodate any standard transformer stamping, so that special dies will not be required to produce the specimens of the test. In the newer types of the instrument, the mercury cups will be supplanted by contact sleeve of special design, but the general form of the apparatus remains unchanged. The conductors consist of No. 0 B. & S. bare copper wire, which fit tightly in the holes drilled in the shell, which is built up of vulcanized fiber, no insulation being required on the winding.

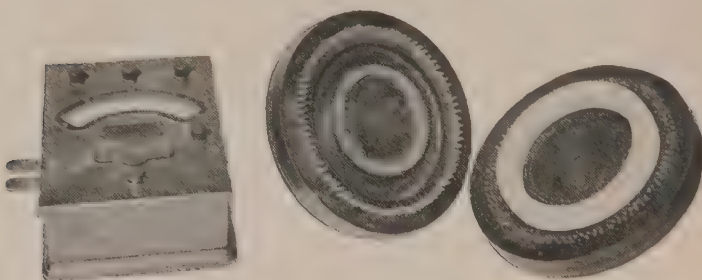


FIG. 1.

To measure the power lost in the circuit, a standard portable Weston wattmeter is used, calibrated as follows: The wattmeter scale was first calibrated to read directly in watts. The apparatus without an iron core, the wattmeter and an ammeter, all in series, were connected to the source of alternating current; the current was varied by steps of one ampère, and the wattmeter reading for each value of current was indicated on the scale. Since there was no iron within the coil, the wattmeter readings under this condition indicate the copper loss for the successive values of current.

To test a sample of iron for its magnetic losses, it is only necessary to select a number of stampings, weigh and place them in the recess provided and close the coil, connect the

apparatus, ammeter and the wattmeter to a source of alternating current of known frequency, as shown in Fig. 2. The current should now be brought to the first desired value and the difference between the wattmeter reading and the reading given when the apparatus contained no iron, for the same value of current, noted. This difference represents the iron losses for the corresponding value of current. This process can be continued throughout the entire range of the current capacity of the instrument, which is 25 ampères.

The time consumed in making a test after the stampings have been prepared is but a few minutes, and trifling in comparison with some of the other methods of obtaining the same data. In the apparatus shown in Fig. 1, the coil consists of two layers of 90 turns each, which, with the current of 20 ampères,

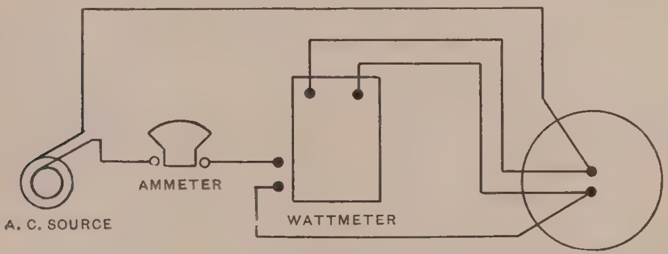


FIG. 2.

brings the iron to a density of about 100,000 lines per square inch, which is in excess of the magnetic densities used in actual practice.

A number of tests have been made to ascertain whether or not there was any appreciable variation in the resistance of the coil, and also to find if the loss when the iron was removed was greatly affected by the frequency, with the result that under ordinary conditions of operation, say with currents up to 15 or 20 ampères, the temperature range was so small as to inappreciably affect the copper loss. A change of frequency showed practically no effect upon the loss when the iron was removed. This would indicate that a single careful calibration at a standard frequency would be all that is required for the wattmeter.

In a paper presented before the American Institute of Electrical Engineers the author has shown that the iron loss is dependent to a marked degree upon the distribution of the magnetic flux in the circuit, which would indicate that if accurate results are desired of a sample of iron it should be tested in as nearly as possible the form in which it is afterward to be used. It is claimed for this piece of apparatus that it is direct reading, it is not affected by magnetic fields, vibrations, etc. The samples for test are easily prepared and require no winding whatever, and the form of the sample is in very close accord with the magnetic circuit of the transformer.

The author's attention has recently been called to the fact that a large transformer manufacturing company purchases a large amount of the sheet steel used from a rolling mill some hundreds of miles distant. Upon the receipt of a shipment of iron a transformer is promptly built from stampings made of sheets selected from the shipment, and the iron loss of this transformer is measured by the wattmeter method. If the test indicates that the iron is up to standard, the entire shipment is accepted; if not, the iron is returned to the manufacturer for re-annealing.

With such an apparatus as has been herein described more frequent tests of the product of the rolling mills may be made, which should result in avoiding difficulties of the nature just cited, and also in the improvement of the quality of the product.

THE UNITED STATES ROAD MATERIAL LABORATORY: ITS AIMS AND METHODS.

By Logan Waller Page and Allerton S. Cushman.

Historic Review of Road Material Tests.

It is only of comparatively late years that the tests of materials of construction have been carried on in a systematic way, and the history of the tests of road materials is of still more recent date. Doubtless the ancient Roman engineer satisfied himself of the suitability of his materials to the end in view, but this was probably done in a very general way, or some records would have come down to us of the methods employed. Many of the earlier writers on macadam road-building noted the superiority of wear in certain varieties of rock, and reference is often made to the desirability of hard and tough rock. As early as the middle of this century compression tests were made on rocks in the endeavor to determine their road-building quality. The systematic testing of road materials may be said, however, to have first started in France during the seventies, where it has been steadily developed ever since. The Portuguese government was the next to take up the subject, adopted some of the French tests and conducted them with much precision. While the importance of the subject has been recognized in England, yet, aside from the limited investigations of a few individuals, almost nothing has been done. The same is even to a greater extent true of Germany, and the other Continental nations have left the subject practically untouched. The United States is the only other country where this work has been carried on in a systematic way.

In 1893 the Massachusetts Highway Commission, in collaboration with the Lawrence Scientific School of Harvard University, established a road material laboratory at the latter institution. Although the testing of paving brick was begun previous to this date, this was the first laboratory in the United States for testing road materials in a systematic way. The Deval abrasion

test was adopted, and tests for determining the cementing power of rock dust were first developed here. Since then, laboratories have been equipped with appliances for testing road materials at Maryland Geological Survey, Columbia University, Wisconsin Geological Survey, Cornell University, the University of California, and the Road Material Laboratory of the Department of Agriculture.

Test of Road Materials in France.—In December, 1878, the French Commission on national roads decided to introduce certain mechanical tests at the laboratory of the School of Roads and Bridges, to be conducted in addition to and parallel with the road tests. A test, known by the name of its designer as the Deval test, for determining the resistance offered by road materials to abrasion had already been found to be reliable by the street department of the city of Paris in testing the rock used in contract work and for selecting new quarries. This test having proved satisfactory, was accordingly adopted by the commission and a laboratory was founded which has steadily increased in usefulness.

Before proceeding with an account of the methods of testing at present in use in this country, it will be necessary to consider the three chief qualities essential to good road materials. These are hardness, toughness and cementing or binding power. Although these properties (at least hardness and toughness) have been long recognized by those familiar with the subject, yet they have never been properly defined, and the terms have been very much confused. This is not at all surprising, for hardness and toughness are closely related. It would be well, therefore, to define these materials from the road maker's standpoint before going farther.

Hardness.—There is no widely accepted measure of the property of hardness. Even in the case of metals, the hardness of which has received much study, there are many tests based on different conceptions of the term, but all of these tests were designed for substances of a homogeneous nature, and are consequently not at all suited for any of the road materials. Further than this, it can be seen that in their conception of hardness some of the investigators differ much. All of these methods, as well as modifications of them, may be put under two heads: abrasion and penetration.

Different demands of technology give rise to different definitions and methods of test; and the method used in any particular case must give a measure of the value of a new material for the purpose for which it is intended.

Only one test has yet been devised for determining the hardness of road materials. This is the Dorrey test of the French School of Roads and Bridges, and consists in grinding specimens with sand of a standard size and quality. We will understand hardness therefore to be the resistance which a material offers to the displacement of its particles by friction. The measure of hardness will be, inversely, as the loss of weight arising from the scoring by an abrasive agent.

Toughness is understood to mean the power possessed by a material to resist fracture under impact. As the surface of a road is continually subjected to the pounding of traffic, it can be seen that toughness is an important property from the standpoint of the road-builder.

With heterogeneous materials like most of the rocks used in road-building, toughness depends on a number of factors; among these may be mentioned the interlocking crystals, the nature of the crystals themselves, and in some cases on the nature of the cementing or binding agent.

The binding power, or, as it has now come to be called, the cementing value of a road material, is the property possessed by rock dust or other finely divided material found in nature to act as a cement on the coarser fragments composing crushed stone or gravel roads. This property varies not only with different kinds of rocks, but also with those which are practically identical in classification and chemical composition. The absence of cementing value is so pronounced with some varieties of rock that they can never be made to compact with the road-roller or under traffic. As the binder surface of a macadam or gravel road is most exposed to the action of wind and rain, as well as the wear and tear of traffic, it can be seen that the presence of this property is most essential to good results. The impervious shell obtained by the use of a rock of high cementing value gives the greatest protection to the foundation of a road. It is a matter of common observation that a good surface which binds well is

less dusty and less muddy, while the economy is great, as it is only the loose unbound material which is ordinarily carried away by wind and water.

In view therefore of the importance of this property, it has been made the subject of especial study. It was important to know the cause of the cementing value with a view to learning if anything could be done to modify the conditions of service.

From an investigation carried on in the laboratory,* it appears that this property is undoubtedly related to that of plasticity in clays, and, in a few words, is due to amorphous colloid particles which, by reason of their characteristic porous structure, are able to absorb water, thereupon assuming a plastic and coherent condition. Heating above a certain temperature destroys this structure, and the powder no longer possesses the slightest cementing value. It is hoped that this theoretical investigation will lead to important practical developments.

THE ROAD MATERIAL LABORATORY OF THE BUREAU OF CHEMISTRY.

The Road Material Laboratory was established in December, 1900, in the United States Department of Agriculture. Up to the present time about four hundred and fifty samples have been reported on, representing a geographical distribution over thirty-eight States of the Union, including a number of samples from Cuba.

The aim of this laboratory is to make standard tests on road materials, free of charge, for any citizen of the United States. In addition to this, allied problems may be presented for study, such as the suitability of clays for the manufacture of paving bricks, drain tiles, cements, etc.; the testing of cements and concretes for road foundations, drains, gutters and highway bridges. It is the intention of the Department to aid as far as possible in the solution of all the problems of road-building, but more particularly with reference to rural highways. It is not,

* On the Cause of the Cementing Value of Rock Powders and the Plasticity of Clays. By Allerton S. Cushman, Jour. Am. Chem. Soc., May, 1903.

however, the policy of the Department to undertake scientific investigations or tests of materials for manufacturers or others who desire to use the information thus acquired to promote commercial ends. The tests as at present carried on are as follows:

Abrasion Test.—A modified form of the Deval machine as adopted by the French School of Roads and Bridges is used for this test. It consists essentially of four cast-iron cylinders, into which samples of the rock, broken to a size between 3 and 6 cm., are put. Five kilograms are taken for the test. The iron cylinders are fastened to a shaft, so that the axis of each cylinder is at an angle of 30 degrees with the axis of rotation. The shaft which holds the cylinders is supported on bearings and has at one end a pulley wheel by which the cylinders are revolved, and at the other end a revolution counter. In the test the cylinders revolve at the rate of 2000 revolutions per hour for five hours. The fragments of stone are thrown from one end of the cylinder to the other twice in each revolution. They thus grind and pound against one another and against the ends of the cylinder. At the end of 10,000 revolutions the contents of the cylinder are removed and placed on a 1-16-inch mesh sieve. The sieve and the fragments of rock remaining on it are then held under running water until all adhering dust is washed off. After the fragments have been dried they are weighed and their weight subtracted from the original five kilograms taken. The difference obtained is the weight of detritus under (1-16 inch) worn off in the test. In the French School a standard rock of superior wearing quality was always placed in one of the cylinders as a standard of comparison, and the ratio of the weight of the dust under 0.16 cm. of the standard rock to that from the rock to be tested was assumed to give the relative resistance to abrasion of the two. It was found, however, that only the best varieties of rock gave less than 100 grams of powder under 0.16 cm., *i. e.*, 20 grs. per kilogram, or 2 per cent. of their weight. The number 20 was therefore adopted as a standard of excellence, and the "coefficient of wear" for any rock tested was obtained by the following formula:

$$\text{Coefficient} = 20 \times \frac{20}{W} = \frac{400}{W}$$

where W is the weight in grams per kilogram of detritus under 0.10 cm. This French coefficient has been in use for many years and is familiar to road-builders, so it is still determined in this laboratory, although many rocks have been found that give a result higher than 20, which is the maximum of the French standard of excellence. Besides the French coefficient, the percentage of material under 0.16 cm. in size is always given.

Cementation Test.—The binding and cementing power of rock dust is such an important element in road-building that much time has been spent in the endeavor to devise a suitable test for determining it. Many have been tried, but as yet only an impact test, carried on in a uniform manner as described below, has given satisfactory results.

One kilogram of the rock to be tested is broken sufficiently small to pass 6 mm., but to be rejected by a 1 mm. mesh screen. It is then placed in a ball mill and allowed to grind for two hours and a half. This ball mill contains two chilled iron balls which weigh 25 pounds each, and is revolved at the rate of 2000 revolutions per hour. It was found by experiment that two hours and a half of grinding on rock thus prepared was sufficient to reduce it to a powder that would pass through a 0.25 mm. mesh. The dust thus obtained is mixed with water to about the consistency of a stiff "dough," and is kept in a closed jar for twenty-four hours. About 25 grams of this "dough" is then placed in a cylindrical metal die, 25 mm. in diameter. A closely fitting plug, supported by guide-rods, is inserted over the material, which is then subjected to a pressure of 100 kilograms per square centimeter. It is most important in making these briquettes that they should be compressed in a uniform manner, and for this a special machine has been designed. The height of the briquette should be 25 mm. If the first briquette is not the right height the requisite amount of material is added or subtracted to make the height of the next briquette the required 25 mm. Five briquettes are made from each test sample and are allowed to dry twelve hours in air and twelve hours in a steam bath. After cooling in a desiccator they are tested by impact in a machine especially designed for the purpose. In a few words, this machine, which is built on the pile-driver system, records the number of

blows of a 1-kilogram hammer, which falls from a measured height upon an intervening flat-ended plunger which rests lightly upon the test piece. The height of blow adopted for this test is 1 cm., and the blow is repeated until failure of the test piece occurs. The cementing value is taken as the number of blows producing failure.*

The problem of holding the test piece rigidly under the intervening plunger so that it shall not be subjected to lateral movements and transverse strains is one which has given much difficulty. Until recently a small brass plate with a beveled hole slightly larger than the diameter of the briquette was used, but it was found that the test piece was often seriously abraded by the side thrust developed. Later attempts to secure the briquette by various clamping devices were not satisfactory. Finally, the method was adopted of placing a drop of thick shellac on the bottom of the test piece, which caused it to adhere firmly to the bed-plate. Careful attention to such details as these is necessary in order to get satisfactory results from this test.

The original method for molding the briquettes was worked out in the laboratory of the Massachusetts Highway Commission and differs somewhat from the method as described above.

In the earlier practice the requisite amount of rock dust to make a briquette was weighed out while dry, mixed with 3 to 4 cubic centimeters of water, and the briquettes immediately molded from the wet dust. It is well known to practical road-builders that the binding power of many rocks increases as time goes on, under the combined influence of water and traffic. This question has received a great deal of attention and investigation in this laboratory. Experiments have shown that the cementing value is increased if the "dough" made from a rock dust is allowed to stand for some time before being molded, and it is still more increased if the "dough" is kneaded. It is of the utmost importance that the operations of the test should be conducted under uniform conditions. In mixing the dust with water to form the "dough" the operator should be trained to knead each specimen

* For full details of this test, see Bulletin No. 79, Road Material Laboratory, Bureau of Chemistry, U. S. Department of Agriculture, 1903.

as nearly as possible in the same manner for the same length of time. After twenty-four hours' standing in a closed jar a cementing value is developed which remains fairly constant. When carried out in a uniform manner by a skilled operator this test has probably no higher percentage of variation than is found in testing the tensile strength of cement briquettes. The test is undoubtedly of the highest comparative value, for it enables us to distinguish between good, bad, and indifferent binding materials.

Test for Toughness.—This test is made on 25 x 25 mm. rock cylinders, with an impact machine especially designed for the purpose, similar in principle to the machine used in the cementation test. A 2-kilogram hammer is used, and instead of a flat end plunger, a plunger with the lower and bearing surface of spherical shape having a radius of 1 cm. is used. It can be seen that the blow as delivered through a spherical-end plunger approximates as nearly as practicable the blows of traffic. Besides this, it has the further advantage of not requiring great exactness in getting the two bearing surfaces of the test piece parallel, as the entire load is applied at one point on the upper surface. The test consists of a 1 cm. fall of the hammer and an increased fall of 1 cm. for each succeeding blow until failure of the test piece occurs. The number of blows required to destroy the test piece is used to represent the toughness. A core-saw, with the cutting edge of the drill set with bort, is used in preparing the test pieces.

Absorption Test.—The method used for determining the absorptiveness of rock is not intended to give the porosity, but merely to obtain the number of pounds of water absorbed by a cubic foot of rock in ninety-six hours, determined from small samples. A smoothly-worn stone, between 20 and 60 grams in weight, which has been through the abrasion test, is used. After being weighed in air it is immersed in water and immediately re-weighed in water. After ninety-six hours of immersion it is again weighed in water. The absorption is obtained by the following formula:

$$\text{No. of lbs. of water absorbed by a cu. ft. of rock} = \frac{C - B}{A - B} \times 62.5,$$

in which A is equal to the weight in air, B the weight in water immediately after immersion, C the weight in water after absorp-

tion for ninety-six hours, and 62.5 the weight of a cubic foot of water. From these weights, the specific gravity and the weight per cubic foot of the rocks are determined.

Specific Gravity and Weight per Cubic Foot.—The specific gravity and weight per cubic foot of all rock samples are calculated from the same weights used for determining the absorption.

Hardness.—The laboratory is equipped with a Dorry machine for testing the hardness of material according to the standard methods of the French School of Roads and Bridges. Cylinders of rock similar to those used in the toughness test are clamped in such a position in this machine that the flat end of the cylindrical test piece is pressed with a standard pressure against a revolving disc of iron on which a quartz sand of a standard degree of fineness, together with a definite quantity of water, is continually being fed. The machine is run at a standard rate for a given number of revolutions, using at the same time the specified amount of sand. The hardness is measured by the loss in weight of the test piece.

Compression and Tensile Strength.—The laboratory is equipped with a 200,000 universal Riehlé machine. Although compression and tensile strength tests do not form part of the routine examination of a road material, they are often of the highest value in special cases.

Tests of Paving Brick.—Paving bricks are tested in the standard rattler as adopted by the National Brick Manufacturers' Association.

Classification of Materials.—For the classification and naming of materials, special modifications of petrographic and chemical analysis have been adopted which need not be described here.

THE APPLICATION OF LABORATORY RESULTS TO PRACTICE.

The proper interpretation and application of the results obtained in the laboratory are quite as important as the general accuracy and appropriateness of the tests themselves. It is probable that many engineers and others interested in the subject of road-building who have only found time to superficially examine the question, have completely misunderstood the bearing and

value of road-material testing. The necessary qualities of road materials must be considered from the double standpoint of furnishing a strong, tough, well-drained road foundation, and a hard, coherent binder surface.

Given a number of materials for laboratory examination, it is not pretended that an actual practical grade of excellence can be established: but, on the other hand, where a choice of material is available, it is quite possible for the laboratory to point out which material should yield the best results both as to immediate excellence and length of life under known conditions of climate and traffic. Undoubtedly in many cases large sums of money have been wasted in building roads from unfit material, which might have been saved by reference to the laboratory. If, for instance, it is desired to know whether an available rock will be useful as a top dressing to form the binder surface, no better method of obtaining preliminary information on the subject is known than to test the cementing value. Undoubtedly some rocks will yield powder which shows very wide variations in the value of successive test pieces under the conditions of the test, but there is at present no difficulty in distinguishing between good and bad material.

It has already been stated that a road material cannot be selected irrespective of the volume and character of the traffic and climatic conditions to which it is to be subjected, without the risk of failure. When the very great cost, even of rural highways, is considered, it is evident that it is gross negligence not to use every preliminary precaution to guard against expensive mistakes.

To properly designate the conditions best suited for a particular material it soon became evident that traffic had to be classified in groups, according to its volume and character. The following five groups were, therefore, selected: city, urban, suburban, highway, and country road traffic, respectively. City traffic is a traffic so great that no macadam road can withstand it, and is such as exists on the business streets of large cities. For such a traffic, stone and wood blocks, asphalt, brick, or some such materials, are necessary. Urban traffic is such as exists on city streets which are not subjected to continuous heavy

teaming, but which have to withstand very heavy wear and require the hardest and toughest macadam rock, or other highly resistant material. Suburban traffic is such as is common in the suburbs of a city and the main streets of country towns. Highway traffic is a traffic equal to that of the main country roads. Country road traffic is a traffic equal to that of the less frequented country roads.

This classification is purely arbitrary, but it serves the purpose for which it was intended, and each group can be approximately identified by a road-builder. City traffic requires the hardest and toughest materials available of the highest wearing qualities. Urban traffic requires such material as asphalt, brick, wood-block, bituminous macadam among the manufactured materials; and if ordinary macadam is used, a rock of the highest hardness, toughness, and wearing quality.

For a suburban traffic the best rock would be one of high toughness, but of less hardness than for urban traffic. For highway traffic a rock of medium hardness and toughness is best. For country road traffic it is best to use a comparatively soft rock of medium toughness.

If the best results are desired on a macadam road, that rock should be selected which would resist the wear of the traffic to which it is subjected only to the degree of supplying just a sufficient amount of binding material to cement the road. Too much or too little wear is alike injurious. The higher the cementing value of the rock the smaller the wear necessary. When a road is first constructed, a sufficient amount of binding material must be supplied to cause the road to "come down" under the roller or traffic. If the subsequent traffic is not sufficient to wear off the requisite amount of binder to replace that carried off by wind and rain the road "ravels." If the traffic wears off an excess of binding material, mud, and dust follows. In either case the material is not well suited to the conditions. In the first case a softer rock should be used; in the latter, a harder, tougher rock, and in all cases a rock of high binding power. As an illustration of this, if a country road or a city parkway, where only light traffic prevails, were built of a very hard and tough rock with a high cementing value, neither

the best, nor, if a softer rock were available, the cheapest results would be obtained. Such a rock would so effectively resist the wear of a light traffic that the amount of fine dust worn off would be carried away by wind and rain faster than it would be supplied by wear. Consequently, the binder supplied by wear would be insufficient, and if not supplied from some other source the road would soon go to pieces. The first cost of such a rock would be in most instances greater than that of a softer one, and the necessary repairs resulting from its use would also be very expensive.

Rocks belonging to the same species and having the same name, such as traps, granites, quartzites, etc., vary almost as much in different localities in their physical properties as they do from rocks of distinct species. It is impossible, therefore, to classify rocks for road-building by simply giving their specific names. It can be said, however, that certain species of rock possess a tendency toward certain properties. For instance, the trap* rocks as a class are hard and tough and usually have binding power, and consequently stand heavy traffic well; for this reason they are frequently spoken of as the best rocks for road building. This, however, is not always true, for numerous examples can be shown where trap rock having the above properties in the highest degree has failed to give good results on light traffic roads. The reason trap rock has gained so much favor with road-builders is because a large majority of macadam roads in our country are built to stand an urban traffic, and the traps stand such a traffic better than any other single class of rocks. There are, however, other rocks that will stand an urban traffic perfectly well, and there are traps that are not sufficiently hard and tough for a suburban or highway traffic. The granites are generally brittle, and many of them do not bind well, but there are some which when used under proper conditions make excellent roads. The felsites are usually very hard and brittle

* This term is derived from the Swedish word *trappa*, meaning steps, and was originally applied to crystallized basalts of the coast of Sweden, which much resemble steps in appearance. As now used by road builders, it embraces a large variety of igneous rocks, chiefly those of fine crystalline structure and of dark-blue, gray, and green colors. They are generally diabases, diorites, trachytes, and basalts.

and may have excellent binding power, some varieties being suitable for the heaviest macadam traffic. Limestones vary greatly, but generally bind well, are soft, and frequently improve under traffic. Quartzites are almost always very hard, brittle, and have very low binding power. The slates are usually soft, brittle and lack binding power.

Those who are familiar with the problems of rural road-building know the great difficulty of selecting among the materials available for a particular road the one which will give the best results for the least cost of construction and maintenance. There are, undoubtedly, practical road-builders whose judgment on the road-making quality of a rock is excellent. But experience with materials of construction in general has proved that it is wise and economical to test the physical properties of material before entering on the expenditure of large sums of money. Co-operation among the increasing number of laboratories in the country is much needed, and standard methods of testing should be adopted. Bridge-building would not have become the high art that it has had not the careful and systematic testing of materials put into the hands of the engineer preliminary data on which to base his calculations and estimates. It is hoped that before long intelligent co-operation will create the same conditions in road-building.

DISCUSSION.

Mr. Swain.

George F. Swain.—I have listened with a great deal of interest to this paper, and I think the Society is greatly indebted to Mr. Cushman for presenting it. I wish to make one correction to his historic remarks. I understood him to say the first laboratory work in connection with testing road materials was done in 1893 in connection with the Lawrence Scientific School, and I wish to say that in 1890 the Massachusetts Institute of Technology installed some apparatus for testing road materials, including a foundry rattler and a machine for testing hardness and wearing qualities.

Mr. Page.

L. W. Page.—I am responsible for that statement. I am sorry that I never heard of these tests before, and am surprised, as I have many times visited this laboratory. I have never seen any of the apparatus used and am sure nothing has been written on the subject. Were any tests ever made? Of course, I am willing to make the correction, on Professor Swain's statement.

Mr. Swain.

Mr. Swain.—Yes, sir; thesis work on the subject was done by the students. I am sure that this apparatus was installed previous to 1893, and the writer of the paper could have seen the apparatus on his visits to the Institute.

Mr. Johnson.

A. N. Johnson.—Our laboratory at the Maryland Geological Survey, at the Johns Hopkins University, was the second to take up the systematic testing of macadum materials. To my mind, the most important point brought out by the paper of Mr. Cushman and Mr. Page is the necessity for standardizing the cementation test of rock dust. We had no sooner undertaken this work than we very soon found out that it was difficult to duplicate our own results, and that there was a wide difference between the results of our laboratory and those of the Massachusetts Highway Commission. We made a comparison of the work by testing briquettes at each laboratory, made from dust prepared at both of the laboratories, and found there was a variation of nearly 75 per cent. in the briquettes which were made from dust sifted at the

different laboratories. With briquettes made at one laboratory Mr. Johnson. but tested at the other a fairly close agreement in the results was obtained. This led us to believe that the great variation before noted was due to the difference in the screens whereby different sized particles of dust would be used in making the briquettes.

We had supposed that we were using the same mesh screen as the Massachusetts laboratory, but a careful examination showed that there was a considerable difference, and a microscopic examination of the dust showed that there was sufficient difference in the screens to give much larger particles in one case than in the other. I understand that some of the other laboratories that have taken up this work have experienced a similar difficulty. With the abrasion tests, however, there is no trouble to duplicate results from the same material.

A PRELIMINARY PROGRAM FOR THE TIMBER TEST WORK TO BE UNDERTAKEN BY THE BUREAU OF FORESTRY, UNITED STATES DEPARTMENT OF AGRICULTURE.

By W. K. Hatt.

General.

Prefatory Note.—The speaker, who is on the staff of the Bureau of Forestry assisting in the work of organization of the projected investigation of the mechanical properties of timber, has been asked to represent the Bureau in the discussion of the subject, "A Preliminary Program for the Timber Test Work to Be Undertaken by the Bureau of Forestry, United States Department of Agriculture," before the American Society for Testing Materials.

The subject has been discussed in its general relations by the speaker before the American Society of Civil Engineers at the annual convention held at Asheville, N. C., June 9 to 12, 1903. The proposed methods are here presented more in detail than in the discussion referred to.

Need and Use of Tests.—The Bureau of Forestry has sent out a preliminary circular to many engineers and others interested in the utilization of timber in order to determine the need of future tests and to formulate a plan of procedure. After the content of the investigation and general plan is determined in its general features by such correspondence and preliminary discussion, it is the intention to perfect the arrangement and details of this plan and submit it, involving methods of measurement and experiment, to experts for a record of agreement or disagreement with the proposed methods of test.

The results of the preliminary canvass of those interested in the utilization of timber will be published in due time. The replies to the circular make evident the fact that, far from the belief that the problems connected with timber are not serious because of a partial and growing replacement of timber by other material, there

is a lively appreciation of the importance of a continuous organized study of methods which will economize the use of timber, lengthen its life, and develop the supply by conservative forest management. The determination of the strength values of timber is only a minor part of the general need. In view of the variability of the product, the details of testing operations are considered by many to be of minor importance.

Such useful lines of work as the following have been suggested:

The need of proper determination of the strength of the Pacific Coast woods, fir, spruce, hemlock, and the Eastern spruce and hemlock, which will form the future supply of structural timber, is suggested from many quarters. The determination of the mechanical properties of the various hard woods which probably will form substitutes for hickory and white oak in carriage construction is a matter of importance.

The majority of engineers would be more satisfied with the results of tests of the timber that is actually supplied to the market by the saw-mills (timber of prime quality, average quality, merchantable, square-edged, etc., as modified by the forms and proportion of sticks and by various degrees of seasoning) than by tests conducted on timber collected from the forest and sawed up at the order of the engineer of tests in order to obtain a solution of the various problems which confront the botanist and forester. One prominent user of timber insists that the quotation of the strength of timbers should be made with reference to the size and lengths of sticks, as in his experience the unit values to be used in design should be much smaller as the sticks become larger. The degree to which the values obtained from tests on new material are to be reduced by the inevitable decay which results from their use, is another matter which has been suggested.

The need also is pointed out of uniform standard rules of inspection and grading, involving the determination of the value of the reducing factors due to knots, crooked grain, and sap. A useful work is suggested in the presentation of photographs, etc., of the appearance of sawed lumber of different species.

Shippers demand a determination of the average weight of

different species of timber at different degrees of seasoning as a basis of computation of freight charges.

All unite in the expression of the usefulness of an investigation of the proper methods of preserving and the most advantageous species to be employed in cases where the timber is to be preserved. Questions of the relative life to be expected under different exposures of treated lumber and the question of the strength of such treated lumber, are also matters of importance to many. The proper methods of seasoning, or hastening the seasoning process, of both hard and soft woods, is a matter which might be investigated with great profit.

From the standpoint of the forester, the effect of forest conditions upon the strength of timber is of scientific and practical interest. Such problems as the relative strength of swamp and highland hard woods, first and second growth timbers, etc., suggest themselves, and a demonstration of the appropriate uses of these inferior timbers, as for instance second-growth loblolly pine, which at present are left uncut in the forest, and which improperly influence the future character of the forest, will be of use to the forester.

The relation between the microscopic structure, as length and connection of fiber, and the mechanical properties, is an attractive field of research.

It is evident that the subject of timber investigation is a formidable problem to attack. The ideal procedure would involve laying out a systematic program in advance, including all the problems, so that one part of the field may be covered at one time and the results afterward may fit the general scheme. This plan would, of course, involve testing timber as found in the forest in which all the conditions are known. And yet, while this is true, the speaker agrees with those who believe that the most direct method of getting unit strength values for the engineer is to test timbers in actual sizes as found upon the market. There is some waste of time and duplication of work in this manner of procedure from the standpoint of the complete investigation of all problems, but the usefulness of the results to the parties for whom the tests are designed will practically be much greater than by any other method of procedure. The progress of knowledge

derived from experiment will thus take place in the same manner as that of other materials. In no case has the entire subject been cleared up in a single investigation, however ideal that procedure might be. In all cases care should be taken to determine the species of timber under test and to ascertain the region of growth. The weight, rate of growth, as shown by annual rings and defects, can be made a matter of record. A complete study of species would, of course, involve the examination of the entire tree as cut in the forest.

These remarks upon the usefulness of timber as obtained on the market apply to the problem of the determination of unit values for the engineer.

In general it may be said that our present knowledge of the average mechanical properties of the common species of structural timber is fairly complete, so far as such values may be based on small sticks. The reduction which must be made in case of large timbers of the different merchantable grades and the manner in which these values are affected by forest conditions are matters at present largely unknown. The effect of moisture on the mechanical properties of wood fiber has been well determined, but the proper reducing factors for the effect of moisture in case of large sticks are not determined. Nor are the moisture contents of market timber well known. It is fairly well established that in woods of uniform structure the strength increases with the specific weight. The relations between the mechanical properties of any species are only partially established. The variation of physical and mechanical properties with position in the trunk is well established in the case of Southern pines.

Organization.—The organization of the timber tests presupposes a central laboratory at Washington, D. C., directed by the Bureau of Forestry, and other testing stations at such points as the Pacific Coast, the Mississippi Valley hardwood center, and the North Atlantic region. These testing stations will be under the direction and inspection of the central laboratory, to which copies of all data taken will be sent. All tests will be made under uniform methods prescribed in advance. At each testing station there will be a resident engineer with proper assistants to carry on the work. The timber for tests will be selected by the engineer,

acting in conjunction with a dendrologist and an experienced inspector.

Publication.—In the publications, the results of tests on individual sticks will in all cases be quoted and the data presented in such a way that the user can determine the range of results from which averages are obtained. The data will be marshaled in the form of tables to suit the requirements of users.

Series Proposed.—To summarize the work as planned at present, it may be said that the following series are under consideration:

Tests to determine properties of structural timber.

Series A: Tests of the mechanical and physical properties of market products.—Material will be actual sizes and grades of commercial products. The purpose is to determine moduli for design; to determine the value of woods now considered inferior; to determine the liability to knots and the reducing factors due to these; to arrange a table of standard weights and rules of inspection and grading. Partly to compare the properties of species from different regions. In case of any given species to determine the relative mechanical value of the wood of various kinds of grain and rates of growth.

Tests to determine the effects of variations in the testing process.

Series B.—Effect of rate of application of load, including impact tests.

Series C.—Effect of moisture.

Studies of the effect and efficiency of technological processes.

Series D.—Preservatives.

Series E.—Methods of seasoning.

Series F.—Fire retardants.

For future disposal.

Series G.—Effect of forest conditions.

The tests at present under operation under Series A include tests on the Pacific Coast red fir and hemlock, the North Carolina second-growth loblolly pine, long-leaf pine. An investigation of the mechanical properties of the Southern gums, and Series B and C, are under way. Efforts at present are being directed to engaging the co-operation of the various persons interested in the outlining of a scheme for the investigation of Series D. As yet the

latter series has not been planned. No definite plan of attack has as yet been prepared for the remaining series, E, F and G.

DISCUSSION OF FACTORS AFFECTING TESTING PROCESS.

(*a*) *Variations in Quality and Imperfections.*—It is the common belief that tests on small sticks do not yield unit values applicable to large sticks. It is supposed that the small pieces selected for test are unavoidably of a better average character than large sticks; very often these small pieces are clear and straight-grained. Experimental evidence seems to show that the results of tests by those who test large sticks are lower than the results obtained by those who have experimented on smaller sections.

It seems reasonable to suppose that the modulus of elasticity and the elastic strength of identical material should not be affected by the size of the specimen, provided that the ratio of depth of beam to span be great enough to eliminate the effect of shear. We know, however, that two pieces of wood are far from identical. Yet, in spite of this heterogeneous character of timber, small and large sticks may yield equal moduli, for the reason that the effect of a knot of a given size is more serious in a small stick than in a large stick. And this consideration may explain the fact that, although timber in small sizes is usually more free from knots and other defects than timber of large sizes, the comparison of results of tests of a large stick with a number of tests on small sticks cut from the same large stick shows that there is no significant difference in the average unit values from the large and small sticks. This is what the former Government timber tests have shown.

What the designer wishes to know, however, is the most probable strength of the different sizes of timber and different grades of timber that he is compelled to purchase on the market, as, for instance, the different grades of car sills, stringers and carriage material; their moduli of elasticity under bending, for the stiffness of a beam rather than the strength often determines its size, the manner of failure, whether in fiber stress or horizontal shear. It seems to the speaker that this knowledge can only be

reached through a direct test of the actual market timbers, whose qualities are determined by the saw-mill. A given log is cut in such a way as to furnish the desired products to the best advantage. It is less likely that logs sawed up under the direction of the engineer of tests will yield results comparable with these commercial products. The relation of the strength of large sticks to the small sticks cut from them does not necessarily agree, for instance, with the relation of the quality of a railway stringer and a car sill, both of first-grade merchantable, cut from a given log.

Useful information will be presented by the proposed method of photographing the sticks tested, so that the effect of different kinds of knots and the position of these upon the strength of the different kinds of test pieces may be determined by the individual who examines the reports. In the publication of results of tests, analyses should be presented to determine in some quantitative measure the reduction of the moduli due to the effects of knots, shakes, and crooked grain. Information will also be available concerning the liability of various species to these defects. The former Government publications relating to timber tests have been criticised because no record was made of the quality of the sticks. This criticism will be met in the future by the publication of photographs of the sticks, showing the grain and defects, and a quotation of the market grade of the stick. Tests are now under operation, and will be continued, on sticks of various sizes and grades as purchased on the market.

(*b*) *Number of Tests to Be Made and Sizes to Test.*—The number of tests depends on the uniformity in the timber of each species and upon the end in view. If it is desired to obtain unit values of the strength of red fir stringers, for example, it would be necessary to test, say, twenty stringers of the first grade merchantable red fir, and the same number of second grade merchantable; fifteen select stringers and twelve clear stringers. This should be repeated in case of three markets.

If it is desired to study the effect of forest conditions on the strength of the fiber, or the effect of variations in the testing process, the timber selected should contain as few variables as possible, and the number of tests would naturally be arranged to correspond with the quality of timber obtainable. In case

of these scientific tests, in which the sizes must be chosen so as to eliminate, as far as possible, other variables than the one under examination, it will be necessary to use sizes of timber 3 inches by 3 inches in cross-section or thereabouts, and five tests are to be used for average value.

The method of selecting test pieces to determine the average quality of any tree as compared with another tree has not yet been determined.

In case of tests for the purpose of obtaining unit strength values, actual sizes should in all cases be tested, as, for instance, car-sill sizes, stringer sizes, roof-truss sizes, carriage stock, columns, floor beams, etc. The appropriate sizes would be quite different in the cases of red fir and hickory.

(c) *Rate of Loading.*—At present it is known that the rate of application of the load exercises a very important influence upon the shape of the load-deflection diagram, particularly at the loads just preceding rupture. It is known also, that the deflections under the ordinary quickly applied load in a test, are only one-half of those resulting from the continued application of the same load. The quantitative relations are not well determined, and a further study is imperative. This study has been planned as follows in Appendix I. At present the rate of loading used is such as to cause an increase in fiber stress of about 500 pounds per square inch per minute.

(d) *Moisture.*—The method of determining the moisture contents of the sticks under test, and the use to be made of such moisture determinations in reducing the moduli to a common basis of moisture, are matters that excite a great deal of discussion on the part of operators of tests. A series of tests should be made to determine the proper reducing factors in the case of large timbers as between the green and dried states. While the results of tests on small-sized specimens show that the strength of dry timber is nearly twice that of green timber, it is probable that in many cases no such increase is to be expected on account of the diminution of the shearing strength due to the checking action arising during the drying-out process. An investigation will be made to determine the relation between the different methods of determining moisture in wood and the disturbance

of results due to the presence of volatile oils in the material under examination.

The tests will, in general, be made on green timber, and for this purpose it will be necessary in some cases to bring the sticks artificially to the degree of moisture corresponding to the green state. A sufficient number of sticks will also be tested, after a thorough drying out, to determine the relation between the values in the green state and the dry state. This information, together with the knowledge of the scientific law governing the relation between moisture and strength, unaffected by defects of checking or unequal moisture distribution in beams, will be sufficient to enable the designer to decide upon the reducing factors appropriate to the conditions of service under which the timber is to be used. This condition of service involves usually either entirely dry timber or timber approximately green.

In all cases, however, the moisture content of the timber will be determined by cutting out discs about ¾ inch thick from the section of the beam near rupture and at a quarter point, and drying these discs in an oven at a temperature of 100° C., or else 80° C. This method will determine the necessary empirical reducing factors, and has the further merit that the degree of seasoning of any particular timber can be easily determined by any engineer.

While the variation of moisture throughout the cross-section is very great in air-dried timber, the variation throughout the length of a beam is small (except near ends). In a series of tests of thirty-five "air-dried" red fir beams (16 feet long, 5 inches by 8 inches cross-section) with an average per cent. of moisture of 26 as determined by drying out discs 1 inch thick taken at center and one-quarter points of span, the average variation in moisture of these discs was about 1.35 per cent. This difference of per cent. of moisture exceeded 2 eight times; exceeded 1 seventeen times. The maximum difference was 7.4 per cent., and the minimum was 0 per cent.

Another series of moisture determinations on discs 1¾ inches thick from eleven 12-inch by 16-inch beams of "air-dried" long-leaf pine with a moisture of 30.8 per cent. showed an average variation of moisture between the quarter point and center

of 0.9 per cent. absolute, maximum 2.2 per cent., minimum 0.0 per cent.

Information will also be procured as to the degree of seasoning to be expected in timber as found on the market. A great deal of timber sold as air dried in the yards is only dry on the surface and is practically green in the interior portions. Account of proposed methods in detail is furnished below in Appendix II.

QUANTITIES AND PROPERTIES TO BE MEASURED.

Some or all of the following properties will be measured, as is appropriate to the use of the species:

Mechanical properties of species:

1. Strength.
2. Stiffness.
3. Resilience.
4. Hardness.
5. Brittleness.
6. Penetration of definite-sized punch.
7. Abrasive qualities.
8. Turning qualities.
9. Weight per cubic foot.

Physical properties:

1. Shrinkage and swelling, absorptiveness.
2. Identification by structure.
3. Identification by appearance of sawed lumber.

The above mechanical and physical properties have partly been determined in the former U. S. Government timber investigations. The properties of brittleness and penetration under pressure will be investigated by proper tests. The abrasive qualities have a bearing in the use of wood for paving blocks. The turning qualities under a tool in the lathe must be known in many circumstances. Under the physical properties, the shrinkage is important from the point of view of the manufacturer. The ability to absorb liquids is important in consideration of preservation. Engineers would be glad to be able to determine the species of sawed timber from its appearance in the lumber yard.

There is at present no standard table of weights of lumber for use in settling disputes between manufacturers and transportation companies, and an endeavor to formulate such a table will be made.

KINDS OF TESTS.

The kinds of tests to be made in determining these properties cited will include a part or all of the following:

Bending.—Fiber stress at elastic limit; modulus of rupture; modulus of elasticity; modulus of elastic resilience; modulus of ultimate resilience; calculated horizontal shear at rupture.

Crushing.—End of grain: strength, modulus of elasticity; side of grain: yield point; maximum strength.

Shearing.—Radial, transverse.

Torsion.

Column Tests.

Hardness.

Abrasion Test.

Turning Test.

Impact Test.

Shrinkage Test.

Absorption Test.

METHOD OF TEST.

Outline of Proposed Methods in Detail.—The following is an outline of the methods at present proposed by the Bureau:

Tests on Market Timber.

1. Timber selected, dressed on four sides, and ends squared, described, and given a serial number. A disc to be examined for amount and distribution of moisture. If timber is not green, it is to be brought to a degree of moisture corresponding to green state. If it is to be tested in air-dry or kiln-dry state, it is to be set aside and brought to that state.

2. Timber delivered and photographed.

3. Timber measured and weighed.

4. Timber tested according to method for testing large beams, as given below.

5. Fracture photographed.

6. Discs cut from region of rupture and from one-quarter point for determining moisture and volatile oils.

7. Pieces cut for minor tests and their locations in stick recorded.

8. These small pieces photographed, measured, tested, and then moisture determined.

(*a*) *Bending Tests.*—The points of controversy in relation to this test are:

1. Method of loading.
2. Method of support.
3. Speed of loading.
4. Location of yield point.

1. *Method of Loading.*—The measurement for deflections is most simple when the load is applied at the center of beam. On the other hand, a larger portion of the stick is brought under the maximum stress when the load is applied at two points. In the latter case, however, a longer beam is necessary in order to yield the proper ratio between depth and span, and for the determination of the modulus of elasticity. In the writer's opinion, the simplest method is to apply the load in the center and compute the fiber stress at the point of failure.

2. *Method of Support.*—Provision should be made for bearing surfaces to prevent local crushing. The center bearing block should be curved longitudinally so as to prevent damaging the beam at edge of block.

3. *Speed of Loading and Measurement of Deflection.*—In testing machines with rigid heads, it is sufficiently accurate to measure deflection on one side of beam. Loads should be applied continuously at a fixed speed, and the deflections read "on the run." These deflections may be read from a scale fixed to the side of the beam at the center by means of a steel wire attached to points on the neutral axis directly over the supports and kept taut with a spring. A hand-glass may be used and the deflections read to 0.01 inch, which represents sufficient accuracy in view of the large deflection measured and the variability of the product. Another method allows the load to be applied some seconds before reading deflections. This involves a variability which may be

avoided by the first method. A separate investigation may be made to determine how the results from continuously increasing loads should be modified to apply to fixed loads (see Appendix I.).

4. *Location of Yield Point, or Elastic Limit.*—There is no doubt that there is a point on the load deformation diagram that indicates an increase in deformation sufficiently marked to be of value as a basis of quotation of the yield point. This should be the point against which factors of safety may be fixed. In case of some sticks, this location of the point is a matter of judgment.

This exercise of judgment also exists in case of tests of steel, but to a less extent. It was avoided in the former Government timber tests by the location of an arbitrary point called the apparent elastic limit. This limit was the point of tangency of a line drawn with a slope 50 per cent. greater than the slope of the load-deflection diagram at the origin.

In order to connect the former Government tests with the future tests these two points will be measured:

1. The yield point.
2. The "apparent elastic limit."

Procedure in Large Beam Tests.

1. Measure dimensions of beam and weigh; the weight per cubic foot and specific gravity to be computed for these measurements combined with moisture determinations.

2. Balance beam of testing machine at zero while timber rests on platform. Load, as a rule, to be applied at center.

3. A rate of increase of load will be decided on. Unless reasons to the contrary appear, the speed of application of load will be such as to cause an increase of 500 pounds per square inch fiber stress per minute. The beam to be kept floating beyond the yield point; maximum load to be recorded. Suitable bearing blocks are to be used to prevent local crushing of timber. Such blocks and small tools are to be furnished by the Washington laboratory to other testing stations in order to insure uniformity. Loads are to be applied continuously and deflections read by scale and wire on one side of beam.

4. Trace cracks and describe nature of rupture.

5. Mark out and stamp the sticks to be taken from beam for minor tests.

6. Remove beam from machine and photograph.

7. Cut discs for moisture and volatile oil determinations; also pieces for minor tests.

(*b*) *Determination of Moisture.*—To be determined from three discs cut from region of rupture and one from quarter point. In most cases of green and air-dried sticks, the difference in moisture between center and one-quarter point will not be great enough to demand a disc from the quarter point. The kiln should be a well-ventilated, double-walled kiln.

From region of rupture, three discs, No. 1, $\frac{3}{8}$; No. 2, $\frac{3}{4}$; and No. 3, $\frac{3}{4}$ inch thick, respectively. These first two are to be used in determining the moisture by kiln-drying, as directed below. For the present the third disc is to be tested for volatile oils. The second disc is also to be tested for volatile oils after having been dried out in the kiln. The difference in volatile oils between discs 2 and 3 will indicate the amount of volatile oil driven off from disc No. 2 in kiln, and this amount of volatile oil is to be subtracted from the loss in kiln from disc No. 2, in order to determine the net moisture. A comparison of tests on discs Nos. 1 and 2 will determine the effect of the saw in driving off moisture from discs. The present indications are that the effect of volatile oils in disturbing the moisture determination is so slight that the volatile oil driven off may be neglected. A moisture determination in the dry kiln is to be made on a $\frac{3}{4}$-inch disc from one of the quarter points.

Method for Moisture Determinations.

1. Weigh disc.

2. Put disc in hot-air bath at 100° C., and dry until no greater difference of weight than 0.5 per cent. of the dry weight remains to be determined.

3. Remove and cool in desiccator.

4. Weigh.

5. Determine per cent. of moisture with reference to dry weight.

Method for Volatile Oil Determinations.—In the determination of volatile oils the disc to be analyzed is first reduced to shavings (at present this is done with a plane), quartered, and from 300 to 350 grams carefully weighed out and placed in a tubular brass

retort suitably mounted and at a slight angle. This operation is performed as quickly as possible in order to prevent loss of moisture in the shavings. The retort consists in a steam-jacketed brass tube (30 inches in length by 3 inches in diameter) fitted at each end with a screw cap, through the center of which passes a brass tube (5 inches in length by ¼ inch in diameter). The weighed shavings having been placed in this retort, steam is passed through the jacket by means of suitable openings. Through the upper end of the retort a current of steam from an ordinary steam-generating flask is passed, the lower end being connected with a condenser. This operation is carried on until all of the volatile oils together with the steam have been condensed and collected in a burette. The volatile oils are then separated from the ether, carefully weighed, and the percentage in relation to the weight of the shavings found.

(*c*) *Crushing Test.*

Along the grain.

1. Cut full-sized test pieces from uninjured ends of beams, length to be four diameters.

2. Square ends by saw, measure dimensions, locate knots and defects, and rings per inch.

3. Weigh.

4. Apply load continuously at rate of 1-32 inch per minute, and read amount of deflection corresponding to loads on two deflectometers placed on two opposite sides of discs until failure occurs.

5. Describe character of failure.

6. Determine moisture in test piece by disc method.

7. Compute modulus of elasticity and crushing strength across grain.

Across the Grain.

Method of Making Cross-crushing Tests.—The former U. S. Government tests were made on sticks of definite section and the results gave the load which caused a compression of 3 and 15 per cent., respectively. These results have little significance for other sizes of timber. The method planned will be to apply loads in increments across the stick and measure the accompanying deflections of the piece in order to determine the load at the yield

point of the timber under this load. The maximum load, if any, will be recorded. These tests will be supplemented by what may be termed penetration tests, in which the load required to bring about the penetration of a punch of given area to a given depth will be determined.

1. Use full-size piece from uninjured portion of beam, length to be sufficient to prevent failure by shear along grain.

2. Measure dimensions, locate knots and defects, and rings per inch.

3. Weigh.

4. Apply load in full width of block and along four inches of length. Read loads and deflections with reference to base until failure occurs.

5. Describe character of failure.

6. Determine moisture by disc method.

7. Compute crushing strength per square inch of surface at yield point and at maximum load, if any.

(*d*) *Shearing Test.*—Various methods of determining the shearing strength have been used. The difficulty is to obtain a pure shear unaccompanied by splitting of the test piece due to bending. This difficulty is often met in case of double shear under tension test. The test piece and method of test are more simple in compression than in tension. Compression tests can apparently only be applied properly for the determination of single shear. The latter is more satisfactory in that the failure occurs on only one surface and the exact stress may be determined. The shearing tests are being made in compression in single shear by a machine designed for that purpose. The values obtained by shearing tests on small pieces should be modified by the results of the tests on large beams, for which the shearing stress at the neutral axis should be calculated.

1. Select four test pieces from one cross-section of stick to yield the radial and tangential shearing strength, for close-ringed and wide-ringed timber. These test pieces consist of blocks $3 \times 3\frac{1}{2} \times 1\frac{1}{2}$ inches, with a projecting bead, of dimensions $2 \times 3\frac{1}{2} \times \frac{3}{8}$ inches, which is to be sheared off. The grain of the wood must be parallel to the direction of the projecting bead, which may be slightly undercut.

(*e*) *Column Test.*

1. As in bending test.

2. Loads to be applied continuously and the sidewise deflections measured on two adjacent sides. The ends of the column shall rest directly against the heads of the machine.

3. Describe rupture.

4. Photograph beam.

5. Cut discs for moisture and volatile oil determinations.

(*f*) *Impact Tests.*—In determining the relative brittleness of different timbers, test pieces in compression and bending will be used. In case of compression tests, the test piece, 3 x 3 x 6 inches, will receive blows of increasing height, and the height of blow at which definite failure occurs will be noted. The indication of failure will be the wrinkling of the surface due to the initiation of a shear. In the bending test, the energy of a single blow required to rupture a stick 3 x 3 x 30 inches will be measured, and also the height of blow required to produce a set of specified amount. These measurements will be made on a revolving drum which receives a record from a pencil attached to the hammer. A machine is under construction for this purpose, modified from an impact machine in use at Purdue University.

(*g*) *Torsion Test.*—The torsion test will be made on hard woods to develop those qualities of fiber, possessed to a great degree by hickory, which allow a wood to undergo large deformations throughout a great length of specimen without rupture. Test pieces will be about 1½ inches in diameter and 36 inches long. Loads will be applied continuously, and the corresponding deformations read. The modulus of elasticity in shear and the torsional strength will be computed.

(*h*) *Hardness Test.*—An investigation will be made to determine appropriate methods of test. The method contemplated involves a measurement of the width of scratch made by a prescribed tool under a prescribed pressure.

(*i*) *Abrasion Test.*—The Dorry abrasion machine will be used. In the machine, blocks of wood are held against a revolving table, and abraded by the action of a powder.

(*j*) *Turning Qualities.*—Determined by actual operations. Result photographed.

(*k*) *Shrinkage Test.*—The specimen selected is 3 x 3 x 12 inches, with sides parallel to radial and transverse direction of trunk, and length parallel to fiber. The deformations will be measured during the change from the green to the dry state by the change of position of reference marks on brass nails driven in the wood.

(*l*) *Test of Absorptiveness.*—The amount of various liquids which timber will absorb has a bearing on the problem of preservatives, and will be measured by immersion of dry specimens.

APPENDIX I.

METHOD OF DETERMINING THE EFFECT OF THE RATE OF APPLICATION OF LOAD ON THE STRENGTH OF TIMBER.

(SLIGHTLY MODIFIED FROM A SCHEME PROPOSED BY THE LATE J. B. JOHNSON.)

Material.—A thoroughly seasoned plank of a given species of timber about 3 inches thick is cut up into sticks about 3 inches square for the full length of the plank. The plank should have a straight grain parallel with the sides of the stick, and the same annual rings should be continuous throughout the length of the stick. The sticks cut from the plank should be dressed down to about 2½ inches square, and divided into lengths of about 4 inches. Each test piece should be given its distinctive mark. The test specimens should be truly dressed, and in order that they may not change their moisture conditions with the changing conditions of the atmosphere, they should all be given two coats of shellac varnish. The test pieces having odd numbers ought to be subjected to an ordinary quick test, and those having even numbers ought to be subjected to the "time test."

Method of Test.—The odd-numbered specimens should be tested in a screw machine with a bearing plate adjustable by a spherical bearing. The rate of deformation should be uniform,

so that the maximum strength is reached in about one minute of time. The strength in pounds per square inch should be recorded for each specimen. The "time tests" upon the even-numbered specimens should be made as follows:

Each specimen is loaded with a definite percentage of the average ultimate strength of the two adjoining specimens with even numbers. For instance, test specimen No. 2 will be loaded with a certain percentage (as, for instance, 90 per cent. or 80 per cent. or 70 per cent.) of the average crushing strength of the specimens numbered 1 and 3. The time of failure should be recorded automatically. A method is suggested by which the considerable deformations of the test specimen at the time of failure allows an electric contact device arranged along the side of the specimen, to operate and make a record on a chronograph.

The loads on these specimens will be applied from 100 per cent. down to about 10 per cent. of the crushing strength of the timber. The curve establishing the relation between the strength and the rate of loading would indicate the crushing strength of the timber for a continuous load.

In order to avoid the release of the load due to the small deformation of the specimen or the yielding of part of the machine, it will be necessary to interpose between the testing head and the specimen some form of elastic base, as, for instance, a nest of springs properly housed or enclosed. The elastic base might have a capacity of about 50,000 pounds, with a deformation of 1 to 1½ inches. The slight deformation of the test specimen on the testing machine from day to day will be very small in comparison with the elastic depression of this elastic base. Thus, if the testing machine is put in balance at a given percentage of the crushing strength, it can again be brought into balance at least once a day until failure occurs. In this way the load on the specimen remains practically constant.

If it is desired to use the testing machine in the meantime, the load might be kept on the test specimen by the aid of bolts and clamps, which would preserve the springs of the elastic base at the deflections corresponding to the load which was upon the specimen at the time it was removed from the testing machine. The above remarks apply to the compression test.

BENDING TEST.

Material.—A thoroughly seasoned plank should be selected, about 3 inches thick and 18 feet long. Sticks running the full length of the plank about 3 inches square should be cut out and dressed to about $2\frac{1}{2}$ inches square. Cut each of these into five sticks about 36 inches long. The sticks should be numbered consecutively and given two coats of shellac varnish.

Method of Test.—The odd-numbered sticks should be tested to failure in cross-bending by uniform rate of deformation in about three minutes of time, and the modulus of rupture and modulus of elasticity computed. Test the intermediate sticks, 2 and 4, by placing on them a definite percentage of the average breaking load of the adjacent sticks.

An additional series should be conducted on large beams of clear timber as follows:

Select three beams of long-leaf pine about 12 inches by 16 inches in cross-section by 16 feet long. In case of two of these beams apply loads continuously within the elastic limit, measuring the deformation and obtaining the corresponding return curve of deflections on release of the load. In case of each, beam tests should be made at different rates of speed. The third beam should be tested under loads applied in increments, time being given between each increment to allow the beam to assume the greater portion of its final deflection under each load. The three beams should finally be ruptured at three different speeds, the latter to be fixed by the results obtained from tests on small sticks.

Repeat these tests on beams of red fir.

Repeat these tests on sticks of white oak, 6 inches by 6 inches in cross-section and 80 inches long.

APPENDIX II.

A DISCUSSION ON THE EFFECT OF MOISTURE ON STRENGTH AND STIFFNESS OF TIMBER, TOGETHER WITH A PLAN OF PROCEDURE FOR FUTURE TESTS.

INTRODUCTION.

The effect of moisture on the strength and stiffness of timber is marked. In making comparisons of the strength of various species, or of the same species under various conditions, the amount and distribution of moisture at the time of test and the law connecting moisture and strength must be known.

It is not a difficult problem to determine this law for small pieces of straight-grained timber for the various tests and various species, especially in compression tests. From the point of view of the experimenter, the difficulty lies in the application of this law, derived from small sticks, to large sticks, in which the moisture is not distributed uniformly. The actual point of failure contains an unknown degree of moisture different from the average of the section (*e. g.*, 10 per cent. as against 30 per cent.), and in the reduction of the observed strength at the percentage of moisture of the average disc to the strength in the green state, the law holding for small sticks of uniform size will not apply. It may be noted, however, in favor of the law determined from small uniformly dry sticks that the timber as contemplated by the designer and afterward loaded is usually uniformly air dry. While timber may be green when delivered to the construction of a building, opportunity usually exists for uniform drying out before final loads are applied. Provided the actual full-sized sticks are tested when green, corrected reductions may be made.

However, the fact that almost all species of timber usually checks, and checks to a variable degree,* on seasoning, will modify the deductions from the moisture-strength law.† The simplest plan is to test the timber either entirely green or uniformly

* Oak, for instance, checks nearly twice as deep as does pine.

† See tests by Professor Bovey, quoted below.

shed dry. Assuming, however, that tests are not conducted under these conditions, the questions that are to be answered are these:

What is the practical use of moisture determinations in the large beams? How shall the reductions be made?

THE USE OF MOISTURE DETERMINATIONS.

The investigator desires:

(*a*) *To reduce results and comparisons of tests* to the same moisture basis, so that in quoting relative strength of timbers under different conditions the comparisons may be fair.

(*b*) *To give to the designer the strength values proper for use* at the degree of moisture he expects in the structure. What is this degree of moisture? In trestles the loads must be carried at times when the timber is green. In buildings, derricks, roof-trusses, the loads may or may not be carried while the timber is green. Large timbers bear loads when only the outside skin of the timber is dry. Some timber, as in buildings, is used under conditions where it may have to bear only a portion of the final load when green; and subsequently assumes the dry condition before the maximum load is imposed. Again, in various climates various conditions of moisture occur. Unit values for strength and stiffness should be listed at a definite per cent. of moisture with a quotation of the law of dependence of these on moisture. In many cases the unit values for design should be based on green timber. Some additional comment should, however, be made on:

1. The effect of seasoning in producing checks.

2. The different percentages of moisture retained in various species when yard dry, kiln dry, etc.

METHOD OF MAKING THE REDUCTIONS.

(*a*) *By application of law* derived from tests on small-sized pieces.

(*b*) *By tests of large-sized pieces* involving the actual distribution of moisture, effect of checking, crooked grain, etc., thus obtaining an empirical law.

If practicable the second method is much safer.

(*a*) Scientific law derived from tests on small pieces.

The scientific problem is simple and may be solved as directed below. To determine the effect of one variable in a heterogeneous material like timber, care must be taken to eliminate as far as possible the other variables. Efforts have been made in this direction by Bauschinger* and in the U. S. Timber Tests.†

1. *Bauschinger's Tests.*—Tests by Bauschinger on small-sized pieces of conifers in *compression* at three degrees of moisture: On basis of wet weight, 40, 14.6, 8.2 per cent.; or on basis of dry weight, 59, 17 and 9 per cent. Forty different sticks were tested, and the law determined for each. In case of each stick there were four test pieces at each degree of moisture. The sticks were about $3\frac{3}{4}$ inches square. The moisture determinations were made on sawdust, and later on the pieces themselves. The curves showing character of moisture-strength law substantially agree in all forty cases. The indications are:

(PROBABLY FOR SAWDUST DETERMINATIONS.)

Per cent. of moisture on basis of wet weight	$\left\{\begin{matrix}33\\59\end{matrix}\right\}$	20	15	10
Per cent. of moisture on basis of dry weight	33	25	20	11
Relative strength	100	120	143	186
Or, more conveniently,				
Per cent. of moisture on basis of dry weight	33	20	15	10
Relative strength	100	140	160	240

2. *U. S. Timber Tests.*—U. S. Timber Tests on sapwood of short-leaf pine showing that reabsorbed moisture has same effect as original sap. Moisture was presumably determined by drying out discs at 100° C. (See Circular 15, p. 3, section 7.)

Per cent. of dry weight	33	20	15	10
Relative strength	100	123	145	180

These two determinations, Bauschinger's and those of the U. S. Timber Tests, do not agree. On account of difference of method we cannot compare the two results.

* Mitt. München—Bauschinger, Heft XIX.

† Materials of Construction—J. B. Johnson, p. 668.

3. *U. S. Timber Tests* (*unpublished*).—In Circular 15, Division of Forestry, p. 3, the statement is made in section 5:

"To determine more exactly the relation of moisture to strength, a series of tests on small pieces of *fourteen species* was instituted, involving 1,866 mechanical tests (on 2 x 2 x 30-inch pieces from six-foot logs) and 933 moisture demonstrations. The results obtained on the general series of 4 x 4-inch sticks were fully confirmed, the difference in strength between green and dry wood appearing if anything even greater for the small sizes."

These results have not been published, except in one case in Johnson's *Materials of Construction*, pages 669 and 676, where the law for oak is given for small pieces, 224 tests.

OAK—COMPRESSION.

Per cent. of moisture, dry weight	33	20	15	10
Relative strength	100	123	144	170

From (2) and (3) the deduction is that there is no important difference between sapwood of short-leaf pine and oak in the effect of moisture.

Bauschinger made a few tests in bending to determine effect of moisture. They do not seem, however, useful.

(*b*) Reducing factors derived from tests on larger beams.

On account of the various factors connected with moisture and seasoning, such as unequal distribution of moisture, checking during drying out, etc., which do not appear in tests on small pieces, laws derived from tests on the latter may not be practically as useful as more empirical reducing factors derived from actual tests on large sticks. The latter may be derived from *tests of large beams* of timber selected for that specific purpose; or may result from the analysis of a mass of data giving the strength of various beams of various trees tested at different degrees of moisture. A series of large sticks of identical timber has not yet been tested to determine this law. J. B. Johnson uses the series of Government Timber Tests on various sticks (4 inches by 4 inches in cross-section) for the purpose and derives reduction curves.*

Leaving out of consideration the anomalous results on short-

* See Bulletin 8, Timber Physics, Division of Forestry, p. 22.

leaf pine, these values agree as well as might be expected in case of so heterogeneous a material as wood.

The apparent deductions are from these:

1. The *compression* tests on the 4 x 4-inch pieces are somewhat more affected by moisture than *bending* tests to rupture on 4 x 4-inch pieces as between room-dry and green timber.

2. That within the limits of significant results the reductions for 4 x 4-inch beams and small compression pieces may be taken to be the same. On the average these reducing factors are:

Moisture......	10 per cent.	15 per cent.	20 per cent.	33 per cent.
Factor........	176	143	125	100

The reductions for 4 x 4-inch compression pieces are greater than the above, being

190	156	127	100

It is difficult to determine if these reducing factors are valid for large beams such as 12 x 16 inches in cross-section. If the effect of uniform moisture is alone involved these factors should apply; but inequality of distribution of moisture, knots, and checks may render their application doubtful. The reducing factors for large timbers should thus be checked by a series of tests on different species directed to this specific purpose.

It will thus be best to test all beams either green or uniformly shed dry. It is recognized that a long period of time is necessary to dry large sticks to uniform degree of moisture.

Further knowledge should be obtained of the degree of moisture to be expected in timber of various conditions of exposure. Is 12 per cent. average air dry? What factors of strength should be used for the common "yard-dry" timber that contains a green heart and a dry skin?

METHOD OF DETERMINING THE MOISTURE.

It is recognized in former tests mentioned above that the entire moisture in beam was not determined. That is, there was still moisture in the dried disc.

What is desired is to reduce tests to standard moisture content. Now if this be not absolutely correct there is no practical conse-

quence of a serious nature. If the timber is tested green at x per cent. and dry at y per cent., as determined by disc method, and the reducing factor be determined, then this same reducing factor will hold for other sticks whose moisture is determined by the same disc method. Mere uniformity is desired. It will be well to use some method like the disc method, which an engineer may use to check up the degree of seasoning of the timber he is using. We may reassure ourselves, however, that the moisture remaining in a $\frac{3}{4}$-inch disc is negligible.

It is also recognized that part of that called moisture was volatile oil. Probably this amount is very small in the disc method. The effect of oils on mechanical properties is still unknown. What we desire to know, however, for the purpose of obtaining correct moisture determination is the amount of oils driven off in kiln in process of drying out discs.

Tests on long-leaf pine discs $8 \times 10 \times 1\frac{3}{4}$ inches, with an average percentage of volatile oil of 0.37 per cent., show that about 85 per cent. of this volatile oil is driven off in the process of drying out these discs in an oven at a temperature of 100°. The total volatile matter driven off in the oven from these discs is about 20 per cent. The correction to the moisture per cent., as determined in the process of drying such discs at 100° in the oven, is thus only about two-tenths of 1 per cent.

Two discs of the same size as those mentioned above, with an average per cent. of volatile oils of 1.50 per cent., lost 50 per cent. of these volatile oils in the oven. The total volatile matter averaged 18.6 per cent., and the correct net moisture, after subtracting the volatile oil loss, was 18 per cent.

Two discs of Pacific Coast red fir, $5\frac{1}{2} \times 7 \times 1$ inch dimensions, showed a percentage of volatile oil of 0.04 per cent. The total volatile matter driven off from these discs in an oven at 100° was 18.4 per cent.

It is evident that in these cases no account need be taken of the volatile oils in the determination of moisture by the disc method, for the correction of the moisture determinations, due to the volatilization of the oils, is too small to be of importance, in view of the nature of the problem in hand and the variability of the material under test.

While under a process involving distillation of shavings by steam the resins may be softened and driven off, no such marked effect will follow in the process of drying discs in an air bath at 100°.

In all these cases a comparison of the moisture driven off from these discs, with the moisture driven off from shavings in a vacuum, discloses the fact that about 1 per cent. more volatile matter was driven off from the shavings than from the discs.

The indications of these preliminary results are that the disc method is entirely satisfactory as a means of determining the moisture of beams.

When beams are tested in a green state considerable variation in moisture does not affect the strength; and very simple determinations will suffice to show that the moisture is above 33 per cent., beyond which an increase of moisture does not affect the strength.

PROPOSITIONS FOR METHODS TO BE USED.

1. In general, test timbers for strength values in green condition.

2. To determine the effect of drying, test certain sticks after drying in a kiln, and other sticks in a thoroughly air-dried state. Use these determinations as check points for extremes of curve showing strength-moisture law.

3. To ascertain the variation of moisture in large beams, determine the moisture in case of a number of discs sawed from different parts of the length of experimental sticks. In addition, conduct scientific inquiry as directed below.

4. For determination of moisture in stick under test, cut three discs, Nos. I., II. and III., from region of rupture, and one disc, No. IV., from quarter point of span. Nos. I., II. and IV. are to be $\frac{3}{4}$ inch thick; No. III. is to be $\frac{3}{8}$ inch thick. Nos. I., III. and IV. are to be tested in dry kiln for loss at 100°. No. II. is to be tested for volatile oils. No. I. is to be tested for volatile oils after having been dried in kiln. This process will determine actual moisture by subtraction of volatile oils lost in kiln, and in addition the moisture lost in sawing.

5. Per cent. of moisture to be calculated on basis of dry weight.

SCHEME FOR DETERMINING THE EFFECT OF MOISTURE AND VOLATILE OILS ON THE STRENGTH AND STIFFNESS OF TIMBER.

Material.—Two methods are available: (*a*) To select a large deal and cut from it the small pieces needed;* (*b*) to go to a lumber yard and select pieces needed of same grain and weight. The grain should be straight and of normal rate of growth, and the pieces should be clear. After obtaining the pieces, they should be graded in proportion to their weight. Material should be air dry. Let us suppose that all variables are removed except weight. Now test three pieces of the lightest weight and three pieces of the heaviest weight, and thus establish factors for use in reducing results of pieces of different weight on the assumption that the strength varies with weight according to a linear law, in case of any given species.

Species.—Red spruce, long-leaf pine, white oak and white ash, balsam fir, Western hemlock, red fir.

Size.—2 x 2 inches or 3 x 3 inches; 36 inches long.

Kind of Tests.—*Shear*, *compression endwise and sidewise*, *bending*, as directed in regular tests.

Method of Procedure.—In all cases determine total moisture and oil in samples by distillation method, and total volatile matter by disc method; also volatile matter by drying out entire test piece. Determine also the actual volatile oil which may be driven off in the disc method. Also determine which is better temperature, 80° or 100° C., for disc method.

TEST FOR EACH SPECIES AND KIND OF TEST.

5 test pieces soaked in water.
5 " dried to about 33 per cent. of moisture and volatile oil.
5 " " " 20 " " " "
5 " " " 15 " " " "
5 " " " 10 " " " "
5 " kiln dried.
5 " kiln dried and allowed to reabsorb 10 per cent. water.
5 " " " " 15 " "
5 " " " " 20 " "
5 " " " " 33 " "

* See Appendix I.

This will give the curve for effect of oil plus moisture, and the backward curve for moisture alone. The difference will be the effect of the oils—provided there were oils to begin with. The matter may be made more clear by another backward series.

5	test pieces kiln dried and allowed to absorb 10 per cent. oil.					
5	"	"	"	" 20	"	"
5	"	"	"	soak in oil.		

Volatile Oil.—Determine the amount of oil driven off in disc method at 100° and at 80° C.

Procedure.—1. Determine volatile oil in original disc.

2a. Take neighboring disc and dry out at 100° and at 80° C. until a constant weight is reached. Then redetermine volatile oils in dried-out disc. Or,

2b. Take a single disc. Select a specimen from certain set of annual rings. Determine volatile oils in this. Dry out the disc in air bath at 80° C., and at 100° C., and select a similar specimen from same set of annual rings. Determine volatile oils in this specimen.

METHOD OF DETERMINING EFFECT OF SAW IN DRYING DISCS.

(SUGGESTED BY MR. LOREN E. HUNT,* BERKELEY, CAL.)

The moisture is determined by drying thin discs, cut through the entire section of the beam and tested in a way similar to the disc method (no account is taken of the volatile oils, however). In order to eliminate the drying effect of the power saw used in cutting the discs, several discs are cut of different thicknesses. Two discs are sufficient for the determination.

The discs are weighed as soon as they are cut. They are then dried at 100° C. until no further appreciable loss in weight is obtained, and the final weight taken. It may be assumed that the moisture removed from each disc by the saw is equal in each set of discs—all conditions being equivalent. Two equa-

* Engineer in charge of timber tests, Pacific Coast Station, University of California.

tions may then be formed with the percentage of moisture and the loss due to the saw as unknowns. Thus,

$$by = (a + x) - b$$
$$dy = (c + x) - d$$

in which

a = weight of larger disc before drying.
b = " " " after "
c = " of smaller " before "
d = " " " after "
x = " of the moisture removed by the saw.
y = percentage of moisture (and volatile oils) with respect to the dry weight of the timber.

whence

$$y = \frac{(a - b) - (c - d)}{b - d}$$

$$x = \frac{ad - bc}{b - d}$$

The following are the results of actual tests. The discs were dried in an ordinary gas oven:

September, 1901—from Redwood Beams.

Discs.	I.	II.	III.
Weight before drying......	60.05	144.15	227.95 gms.
" after "	33.14	76.85	120.30 "

Combining I. and II., x = 3.71 gms.; y = 92.4 per cent.
" I. and III., x = 3.79 " y = 92.6 "
" II. and III., x = 4.07 " y = 92.9 "

Whereas by neglecting the effect of the saw we get, respectively:

81.2 per cent. : 87.6 per cent. : and 89.5 per cent.

The discs were $\frac{1}{2}$ to $\frac{5}{8}$ inch thick. With larger discs the percentage will be smaller, of course, and perhaps may be neglected entirely. With more seasoned timber the effect is less so. For example:

September, 1901—from "Oregon Pine" Beam.

Discs.	I.	II.	III.
Weight before drying......	56.13	91.50	179.35 gms.
" after "	46.60	74.87	145.30 "

Combining I. and II., x = 2.17 gms.; y = 25.1 per cent.
" I. and III., x = 2.04 " y = 24.8 "
" II. and III., x = 1.88 " y = 24.7 "

Whereas neglecting the saw effect we get, respectively:

20.4 per cent. : 22.2 per cent. : and 23.4 per cent.

THE EFFECT OF KILN-DRYING ON THE STRENGTH OF CONIFERS.

Certain results derived by Professor H. T. Bovey, who experimented on Canadian conifers, were reported to the Canadian Society of Civil Engineers in November, 1897. The tests included large beams, both wet and kiln dried, and small specimens cut from these large beams, both wet and kiln dried. Tests were made in bending of large beams, and in tension, compression, and shear of the small pieces. The species included were white pine, red pine, spruce, and hemlock.

These tests give evidence of the effect of moisture; and of the effect of kiln-drying in decreasing the shearing strength of timber. Professor Bovey finds that while kiln-drying the smaller specimens increase their compressional strength relatively to air-dried timber in the proportion of 100 to 175, the shearing strength is thereby decreased in the proportion of 100 to 75. The effect of this kiln-drying on the larger beams is to start checks, or extend checks already existing, so that in some particular cases the beam under test may be considered as rather made up of two beams placed on top of each other than a single united beam. (Whether or not this may be avoided by proper seasoning is an open question.)

He notes that generally kiln-dried beams fail either in tension or by longitudinal shearing. Of nine kiln-dried beams only one failed in the ordinary manner by crippling in compression, while four failed by tearing on the tensile side, and four by longitudinal shear. On the other hand, of the twenty beams not kiln dried, eleven failed by crippling on the compression side, six by longitudinal shear, and three hemlock beams only by tearing in tension. It would seem that the effect of kiln-drying was to increase the compressional strength of the timber to a point where it was equal to the tensile strength, which latter remained unaffected by drying out.

There is little precise indication in these tests as to the effect of kiln-drying on the modulus of elasticity. The marked effect is evident, however, in Professor Bovey's measurements of the behavior of a beam from day to day while carrying a fixed load. On dry days the deflection would be less than on wet

days. For instance, on rainy days the deflection would be 0.120 inch; on dry days, only 0.111 inch. The beam actually responded to the varying hydrometric conditions of the atmosphere and the modulus of elasticity increased as the beam became dryer.

This being so, a beam must be tested very soon after having been removed from the kiln in order to yield results appropriate to the kiln-dried state. Professor Bovey notes that not only are the deflections smaller in the drier state, but also that they are more regular.

Changes of temperature produced no appreciable difference in deflections.

Tests by Naval Constructor Frank W. Hibbs on red fir, as reported in *Proceedings of Pacific Northwest Society of Engineers*, November, 1902, vol. i., No. 2:

These tests were made on 4 x 4-inch sticks, in bending and other tests in tension, compression, and torsion. Samples were fine grained or coarse grained, air dried or kiln dried, and green. No determinations were made of the actual moisture in the sticks at the time of the tests, which was after a period of storage in a cool, dry place. These tests showed that the strength of the kiln-dried sticks was less for all kinds of tests than that of the air-dried sticks. The green timber had a greater strength than the air-dried timber in three kinds of tests, while the green timber had less strength than the air dried timber in three kinds of tests. The differences, however, in all cases were slight—not to exceed 10 per cent.

The remark must therefore be made that, while it is a scientific fact that the actual strength of a wood fiber is increased by the process of drying out the cell walls, the strength of a combination of these fibers of spring and summer growth in the form of a large stick may not follow the same law that is evident in the case of small pieces. This remark must be further modified by saying that proper methods of kiln drying may not diminish the strength to a sufficient degree to reverse the law derived from small sticks. It may be that this will explain the reason why the deductions from the former Government timber tests on 4 x 4-inch sticks agree in character with the experiments on smaller sticks.

DISCUSSION.

Mr. Lanza. GAETANO LANZA.—Inasmuch as I had considerable to do with the preparation of the printed circular, there is not very much for me to say now, but there are a few remarks which it may be well to make.

First, series I.—*i. e.*, "Tests on Timber Collected from the Open Market"—is a very important subject for investigation. Of course, in such a series the complete history of the timber tested cannot be obtained, but the facts that can be obtained are those that the engineer most needs to know. Moreover, the number of tests that have been made upon the various kinds of timber grown and employed in the United States in such sizes as are used in practice is small, whether we consider the total number of such tests or the number of species tested. If asked what strength and stiffness can be expected in the practical use of many Western and other woods, no answer can at present be given, and a series of tests that will furnish an answer to this question, even approximately, cannot fail to be of great importance to the engineer.

Second, in regard to the inadequacy of a series of tests, based primarily upon botanical considerations, we should note the difficulty of recognizing the species after the timber is sawed and transferred to the lumber yards. Thus I understand that not only would it be impossible for the engineer or for the lumber dealer to know, from the appearance of a stick in the lumber yard, whether it was of long-leaf or of short-leaf yellow pine, but also that the botanist himself would be very liable to be mistaken if he attempted to decide the question.

As to the question of the importance of testing full-size pieces, Mr. Hatt has explained it very clearly, and it is only necessary for me to say that, of course, the problem of large pieces is the question of the knots, cracks, and other defects which occur in these pieces and which do not occur in the small pieces. My first tests of timber were made upon spruce beams. I could at

that time take a stick 6 x 12 or 4 x 12, look at each side of it, see how many knots and other defects there were; then guess at the modulus of rupture, proceed to test the beam, and then find that my guess was, as a rule, within 6 per cent. of the truth. That shows very plainly, it seems to me, that the knots, cracks, and defects outweigh almost every other consideration. Mr. Lanza.

Now a word in regard to the selection of the timber in the forest. The botanist going into the woods and selecting the lumber from botanical considerations only would be liable to neglect such questions as the prevalence of knots, the height above the ground where the branches begin to occur, what portion of the timber is liable to be used in practice, and what will be the amount of defects that will occur in that portion. Inasmuch, therefore, as these are vital points in this investigation, it follows that a proper selection can only be made by a man who had either tested timber or who had seen a great many tests on full-sized sticks. In the scheme proposed by the Bureau it is intended to take photographs of all six sides of a stick, and that is a very important matter. If two different men were to undertake to describe how knotty a stick was, I do not think that we could tell much by their description; but if we have the photographs of the six sides these photographs would speak for themselves.

The percentage of moisture is a most important matter, and the question of moisture on full-sized sticks is not the question of moisture on small samples. Thus, suppose that the modulus of rupture of a 2 x 2-inch stick containing 15 per cent. of moisture has to that of one containing 10 per cent. of moisture a certain ratio, it would not be fair to assume that the ratio would be the same in the case of 6 x 12-inch or 8 x 16-inch sticks, inasmuch as this ratio would be very much affected by the knots, cracks, and other defects that occur. The modes of determination of moisture depend largely upon the question of sampling, and this is a matter that can only be settled by careful investigation.

Another matter which should be mentioned is the importance of time tests and a study of the effect of time upon the strength and stiffness of full-size pieces. A certain amount of such tests have been made in my laboratory upon full-size timbers subjected to loads for periods varying from six months to three years.

Mr. Hatt. W. K. HATT (by letter).—In the proposed tests provision is made for time tests on large sticks. It is a well-known fact that timber is weaker under a slowly applied load. For instance, if a car spring is inserted between the knife edge of the testing machine and the timber under test the beam breaks at a lower load than if the knife-edge bears on the beam directly.

This work of determining the mechanical properties of timber is a very important aid to the work of the forester in promoting a conservative management of the forest, as well as of use in supplying valuable information to engineers.

With reference to timber obtained in the open market, I may say that there is no difficulty in finding out the mill and the district from which large timbers come that are obtained from the lumber yards of large dealers. It is thus possible to obtain all the necessary information with regard to the conditions of growth and the extent of the seasoning. No timber is tested whose species is not determined.

It must be recognized that there are a very great number of minor factors which affect the growth of a given tree in our American forests. The attempt to determine the influence of many of these is bound, in the speaker's opinion, to be attended with failure. What mainly determines the volume and quality of wood is the moisture that the tree receives from the soil and the light it receives from above. Each tree struggles with its neighbor for the larger share of these two, and there is also warfare between different species for the possession of the soil. Nature has given plain answer to many of the questions upon which the testing machine is dumb. Moreover, it is not merely the actual quality of the timber produced in a tree, but the volume of merchantable timber that decides the relative value of species or of sites.

In favor of selecting timber from the market it may be noted the conditions which prevail at the period of visit of the collector to the forest are not those which obtained 150 years before. Changes of drainage, the influences of man in introducing competing species into a formerly pure forest, etc., soon change the character of a forest. The collector in the forest does not know as much of the history of the tree as does the collector in the lumber yard, for the latter sees the history of the tree in the annual

rings. In choosing a series of sticks to serve as the basis of an investigation of the relation between mechanical and physical properties a selection may be to most economically made in the lumber yard. Mr. Hatt.

The proper work of the testing machine is to determine the relation between different physical qualities of wood and mechanical strength. It is the business then of the lumberman or forester to use this information in the forest for whatever purpose he may desire to use it. The testing machine can keep itself busy with useful problems of some practical outcome to better advantage than in the pursuit of problems that have no solution.

In relation to the method of making moisture determinations it is reassuring to know that practically all the moisture can be driven out of a $\frac{3}{4}$-inch disc. In view of the great variation of the moisture throughout the cross-section of a piece of timber with the heart practically green, containing 100 per cent. of water, and perhaps 10 per cent. on the outside, and the very great variation in individual sticks of timber, it is not the part of practical wisdom to quarrel over a fractional per cent. of moisture. It is particularly necessary to avoid being lost in the labyrinth of details and useless refinements which are the result of attempting to lay out this investigation of timber from the purely logical standpoint.

THE HISTORY AND ORGANIZATION OF THE INTERNATIONAL RAILWAY CONGRESS.

By P. H. Dudley.

The International Railway Congress is the outgrowth of a scientific congress which met in Brussels in 1885 to celebrate the fiftieth anniversary of the original law for the inauguration of the Belgian railways. The actual date of this was in May, 1884, but the meeting was adjourned until the Antwerp Exposition of August, 1885. The inauguration of railroads in the United States preceded that of the Belgian railways by six years. The idea of organizing a congress of the nature of the International Railway Congress was discussed in Belgium in 1874. It was an idea of M. Fassiaux, the Secretary-General of the Railway Minister, and was intended as a supplement to the Postal and Telegraph Congress.

In June, 1884, a commission of officials of the railways pertaining to the administration of the roads and bridges was appointed by the Minister of Public Works to prepare the programme for the celebration of the fiftieth anniversary of the original railway law. The idea of the Scientific Congress was retained by the Secretary-General of the Railway Ministry. Its object was to investigate improvements to be introduced in railway construction and operating. It was resolved to ask not only governments but railway administrations to lend assistance and send representatives. A technical sub-committee was instructed to draw up a program in conformity with the idea of a scientific congress. This sub-committee submitted a report containing sixteen propositions. Representatives of all the great companies of the administrations of Europe and some from America were present, and an effort was made for the foundation of a General Railway Union. At the session in Brussels it was determined to give it the basis of a scientific association, with the object of encouraging the technical advancement of railways by conferences, by publications, and by facilitating intercourse between affiliated administrations. The motion was passed by acclamation, but to give it effect, it

was indispensable to obtain the assistance of the Belgian Government, and find funds necessary to meet preliminary expenses. This was done by the Minister of Railways, who understood at once the great scientific value of the suggested institution, and encouraged its inauguration. He gave it the assistance of his officials, and granted it a Belgian Government subsidy.

It was at the session held in Milan in 1887 that the Association was established, and the statutes passed as they exist to-day. The Congress is composed of State or private railway administrations, who send a limited number of delegates in proportion to the extent of their system to periodic sessions. Governments were invited, through the Belgian Foreign Office, to send representatives to the sessions. Each railway administration subscribes 100 francs ($20.00), plus 2½ cents per mile of their lines. To be permitted to take part in the Congress, each one should have 37 miles, or 50 kilometers of line, except in the case of certain railways which are operated under special conditions.

The Third Session of the Congress was held in 1889, at Paris, and the Fourth, in 1892, at St. Petersburg. The Fifth, in London, 1895; delegates being present from all countries operating railroads. The writer was a delegate in 1895 to London. The Sixth Session of the Congress was held in Paris, in 1900; the writer being Reporter for the United States on the "Nature of the Metal for Rails." The Seventh Session of the Congress will be held in Washington, D. C., in May, 1905; the writer being Reporter for America on "Rails for Lines with Fast Trains."

The sessions are held now at periods of five years. The work of preparation for the Congress is so extensive that this amount of time is required to collect the information, write, print, and circulate the reports for each session.

The Congress is managed by a permanent Commission, with its headquarters at Brussels. Members of this Commission are appointed from the different countries, and meet at Brussels once in two or three years. The last meeting of this Commission was on the 27th of June, 1903, to prepare for the organization of the coming session at Washington, D. C., in 1905.

A Permanent Committee in Brussels arranges the general program of the session, and indicates as general questions the topics for the different sections of the Congress.

There will be five Sections for the Seventh Session at Washington:

Section I. Ways and Works. Four general questions, and nine reporters, four being from this country.

Section II. Locomotives and Rolling Stock. Four general questions, and eleven reporters, four being from this country.

Section III. Working (or Operating). Four general questions, and nine reporters, five being from this country.

Section IV. General. Four questions, and eleven reporters, three from this country.

Section V. Light Railways. Six reporters. A total of forty-six reporters; sixteen being from this country.

Reporters are appointed from the railroad companies in the different countries to prepare the detailed list of questions from the general topic and submit them to the railroad companies for replies, and then write the report from the information received. On all questions of general interest, a reporter is appointed for the Continental countries and another one for America, to collect the information from the railroad companies of the different countries and prepare separate reports upon the same question and submit them to the Congress for discussion.

The detailed questions by the reporters are sent out over two years in advance of the session. The information is collected, reports prepared and submitted to the Permanent Committee at Brussels a year before the session of the Congress, the time occupied in their publication. The American reporters have requested replies to be made to their questions on or before July 1, 1903.

The Congress issues a *Bulletin*, in which all reports are first published and sent to the different administrations. Then they are prepared in a separate copy for use of the delegates to the Congress.

After the presentation of the reports and discussion in their respective sections, each formulates certain conclusions for adoption. These are presented to the entire Congress for final discussion, adoption, or rejection. They are brief statements of the conclusions which have been submitted by the reporters and the different sections.

Important questions connected with "Ways and Work" have special reports by the sections for each Congress. Questions of

not as much importance are not discussed at each Congress, new questions being formulated by the Permanent Committee.

The reporters serve only for one Congress, unless asked to act a second time, which is the case on important subjects. The question of quality of steel for rails has received attention at each Congress, and will at the coming session, as a special feature under Ways and Works, Question II., "Rails for Lines with Fast Trains."

The theories in reference to the railroads and construction are not alike in the different countries. Those of America are distinct from those abroad in some cases. While discussions of matters pertaining to the permanent way locomotives and rolling stock have received attention at each Congress, principles in reference to them have not been formulated, but possibly may be at the coming Congress, as they are of such great interest and importance.

The questions pertaining to the combined stability between the locomotives and the permanent way have never been completely investigated and stated, owing to the difficulties of ascertaining and defining the complex relations between the moving locomotive and a flexible and elastic superstructure, resting upon its subgrade of limited elasticity but decided plasticity.

New investigations are made for each session of the Congress. Opinions differ in reference to the distribution of stresses in rails under moving locomotives. In bridges, where it has been possible to make calculations for the unit fiber stresses in the different members, great advance has been made, and it is now upon a scientific as well as a practical basis.

The conditions under which the railroads are operated in the different countries have developed distinct types of locomotives and rolling stock. While the general question of transportation may be the same, the conditions under which it is conducted are unlike. In the British Isles the distances are comparatively short, though numbers of trains are required to transport the population in such thickly settled districts. The same is true of portions on the Continent. In the United States our railroads have been constructed for the purpose of developing the country quite as much as accommodating those portions which are thickly settled, and the country is of large area and the distances correspond.

In size of locomotives and weight of trains the development of the railroads in the United States exceeds those of any other

country. Our methods are different, and the constructions and general ideas in reference to the movement of the heavy loads will be of interest to the visiting members of the Congress. The discussions become of advantage and value to all railroad officials.

A *Bulletin* of the International Railway Congress is issued by the General Secretary of the Permanent Committee in Brussels. This was published in French only from 1887 to 1895. Since then an edition is published in English. They are not strictly identical, each one, however, containing, with original and other papers, all the documents and reports of the transactions relative to the sessions of the Congress. There are twelve numbers per year, subscription price, $6.00. The proceedings of the Congress are published for each session. Those for Brussels, 1885, are in two volumes, price, $4.00. Proceedings of the Second Session, in Milan, 1887, three volumes, price, $9.00. Proceedings of the Third Session, Paris, 1889, three volumes, price, $12.00. Proceedings of the Fourth Session, St. Petersburg, 1892, four volumes, $20.00. These have been published only in French. Proceedings of the Fifth Session, London, 1895, four volumes, $17.00. Proceedings of the Sixth Session, Paris, 1900, six volumes, price, 24.00, both in French and English. These will form important additions to libraries and technical societies.

Of interest to the Society will be the opportunity for discussion of questions pertaining to the composition and physical and mechanical properties of the rail section.

The visiting members of the Congress may take this opportunity to make investigations in several questions directly or indirectly connected with the railroads, particularly those pertaining to metallurgical and mechanical processes. The methods of testing materials for bridges and also the question of cements will be of exceeding interest. A new topic for the Congress will be concrete and embedded material for this session.

The American Railway Association, as the American Section of the International Railway Congress, on behalf of the railroad companies, has charge of the arrangements for the Congress in Washington, D. C., 1905. The Secretary is Mr. W. F. Allen, No. 24 Park Place, New York, N. Y.

The Secretary of the Permanent Commission is Mr. L. Weissenbruch, No. 11 Rue de Louvain, Brussels, Belgium.

THE TESTING OF BITUMENS FOR PAVING PURPOSES.

By A. W. Dow.

It is surprising when one considers the large quantity of bitumen used each year, and its numerous applications in the many industries, that more attention has not been given to the study and examination of the physical properties of this interesting class of bodies. Why is it not just as essential to examine into the properties that a bitumen should possess, to meet the requirements of the purpose for which it is to be employed, as to examine a hydraulic cement? There are many million dollars spent on asphalt paving each year, and yet the examination of the materials entering into these pavements is neglected, excepting in one or two instances, and the majority of these are entirely devoid of any real value, as the examinations are not based on a careful study of the requirements and conditions. The only explanation I can offer for this lack of interest or attention to the testing of these materials is that it does not fall within the scope of any of the professions.

The testing of bitumens is devoid of any true chemical methods, and it is evident from their complex composition and great variation in chemical composition that it will be a long time before chemistry will play an important part in the determination of their properties. It is not to be wondered at either that engineers do not consider the testing of bitumens as being within the scope of their profession, as the physical properties and laws governing bituminous construction are so different from those relating to the materials usually met with in engineering work.

At the last annual meeting of the International Association for Testing Materials, the formation of a committee was authorized, known as No. 34 (for the settlement of a uniform definition and nomenclature of bitumen). Dr. Lunge, of Zurich, was appointed chairman, Mr. C. Richardson and myself accepting the American membership. In a circular letter addressed to the members of the committee, Dr. Lunge proposed that the committee not only

devote its attention to the nomenclature, but to arriving at uniform methods of testing bitumens. The establishing of uniform methods in any subject is, of course, very desirable, but it is a question whether the time is ripe for such an undertaking in the field of bitumens, as there has been so little work done in this subject, and by so few persons. The only tests that I believe sufficiently established to warrant any unification in the methods of procedure are those for the determination of the total bitumen and the amount of bitumen soluble in naphtha.

But I do not present this paper with the hopes of establishing any uniform methods at the present time, but more for the purpose of bringing before the Society for discussion the fundamental laws governing asphalt construction and some physical tests which I have adopted for the examination of asphalt materials for determining their suitability for use in paving.

The theory of asphalt construction is but little understood. This is because the proper physical laws are not applied in reasoning on this subject, which is not surprising when we consider that the cementing of other materials in general use in engineering work are solids, and involves the laws governing the cohesion and adhesion of solids for each other, while in the case of asphalt construction we have entirely different principles involved—those governing the cohesion of liquids and adhesion of liquids for solids, for asphalt paving cements are in every sense of the word liquids. It is either because this fact is unknown, disregarded, or thoughtlessly overlooked by analysts and engineers, that the majority of literature on the technical examination of asphalts is so lacking in value.

To better illustrate this, a description of how one class of asphalt pavement is constructed and a discussion of its properties will not be amiss. What is known as a sheet asphalt pavement is one made of a mixture of sand with an asphaltic cement. As the asphaltic cement used is excessively viscous at ordinary temperature, this mixing is of necessity done while the materials are heated to a degree sufficiently high to render the cement so fluid as to readily coat the sand. This mixture of sand and asphaltic cement is spread on the street and compressed into a continuous sheet by means of rolling. These operations are

performed while the mixture is heated, as it is more easily handled and compressed while in this state.

This pavement must have the following properties:

1. It must be composed of such a material that it will not crush or be ground away by traffic at any climatic temperature. To accomplish this the asphaltic cement which surrounds the sand grains must be pliable and elastic at all temperatures, for, if it were solid and rigid the mixture would soon grind away.

2. As an asphalt pavement is laid in one continuous sheet, it is necessary that the cement used be so ductile, even at the lowest temperature obtained, that the pavement may contract without cracking.

3. It is also necessary that the pavement be so firm and hard at the maximum climatic temperature obtained, as to withstand the passage of traffic without either being cut into so badly as to be objectionable, or shoved to the side of the street.

4. The paving mixture must be as dense as is possible, so as to preclude the entrance of water into its voids, for if water enters and freezes the mixture is expanded and becomes spongy, for, with the pavement in such a condition, especially if the asphaltic cement is not very pliable, it will wear away by abrasion.

5. The pavement must not contain any material that is acted on by water, for even though it were possible to construct a paving mixture so dense as to preclude the entrance of water into it, yet the mixture being pliable under the passage of traffic, water will work into it if it contains any material that is readily attacked.

6. The pavement must not contain an asphaltic cement that will age so rapidly as to cause the pavement to lose its pliability before a reasonable period of time.

A pavement possessing all these qualities will be durable under all normal conditions.

Although the use of different sands in a pavement will change its physical properties somewhat, yet they are principally dependent on the physical properties of the asphaltic cement with which it is constructed.

For a pavement to possess the properties above enumerated, it must be made with an asphaltic cement which will be so ductile at the minimum temperature obtained in the climate in which

it is laid as to permit a contraction of the pavement without cracking, while at the same time it must not be rendered so fluid by the maximum climatic temperature as to produce a pavement objectionably soft. The asphaltic cement should possess the property of flowing at all temperatures to which it will be subjected. It is upon this property that the adhesiveness of an asphaltic cement depends. Comparing two asphaltic cements of the same degree of consistency, the one that approaches more closely to being a true liquid possesses the greater adhesiveness. This is true not alone from observation, but is evident when we examine into why a bituminous cement is adhesive. The property of adhering is not chemical, but purely mechanical, and the more fluid the cement is the more completely and perfectly will it flow into every cavity of the surface in which it is in contact, thus producing a more perfect bond or adhesion.

It must not be inferred from the above remarks that the cement which approaches most closely to the true liquid, and for this reason is most adhesive, is the most desirable for asphalt construction. This is not the case, for cements as they approach the condition of being perfect liquids are found to be more susceptible to changes in temperature, that is, more brittle in the cold and more softened by heat.

Besides these physical properties the asphaltic cement must be able to withstand the heating to which it will be subjected in the process of manufacture into pavement, without having its physical properties materially changed, and must not be rapidly hardened or so changed by age as to lose its ductility and pliability in an unreasonably short period of time. For the determination of the above properties I have devised the following tests:

Ductility.—The ductility of an asphaltic cement is determined by ascertaining the distance in centimeters that a prism of the cement can be drawn out before breaking. The size of the prism that I have adopted is one 5 cm. in length and with a square cross-section of 1 cm. The molding of this prism is done as follows: Fig. 1 shows the four pieces which fit together to make the mold. Fig. 2 shows the mold put together ready for filling. Before filling, the mold is placed on a brass plate, and so as to prevent the asphalt adhering this plate and the

inner sides of the two pieces of the mold (*a* and *a′*) are amalgamated. The asphalt cement to be tested is poured into the mold while in a molten state, a slight excess being added to allow for the shrinkage on cooling. After the asphalt cement is nearly cooled the prism section is smoothed off level by means of a trowel, which should be wet with water to prevent its sticking. When it is thoroughly cooled to the temperature at which it is desired to make the test, the clamp and the two side pieces are removed, leaving the prism of asphalt cement held at each end by the ends of the mold that now take the part of clips. The

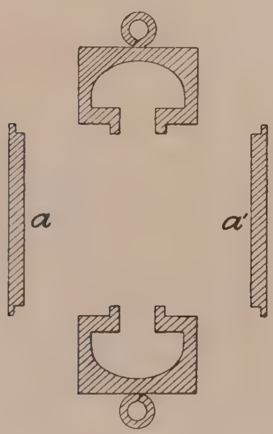


FIG. 1.

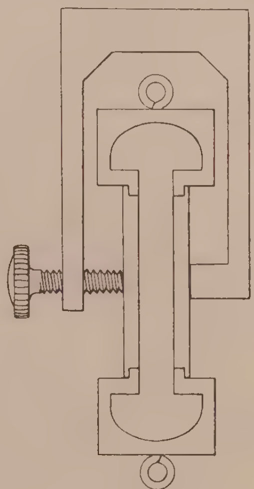


FIG. 2.

test is made by pulling the two clips apart at a uniform rate of speed by means of hooks inserted in the eyes. The prism should be kept in the freezing mixture or water at the temperature desired, and the test made while so immersed so as to insure the temperature remaining constant. The rate of speed adopted for pulling the clips apart when the test is made at 77° F. is 5 cm. a minute, and 1 cm. per minute when making the test at 20° F. Up to the present time I have pulled the clips apart by hand, but am now working on a machine that will do this and at the

same time measure the force required to pull the clips apart at the standard rate of speed. Sufficient work has not been done on the ductility test at low temperatures to be able to state any standard at the present time, but it has been found that it is not safe for an asphalt having a consistency of 40 penetration at 77° F. to pull less than 20 cm. at this temperature in the above ductility test.

Softness at High Temperature.—The softness of an asphaltic cement at high temperature is determined by ascertaining its consistency or penetration by means of the penetrating machine at 32°, 77°, 100° and 115° F. The rate of softening of an asphaltic cement is thus determined, and an idea can be arrived at as to whether it would be too soft for use at the maximum climatic temperature.

The consistency or viscosity of an asphaltic cement is determined by ascertaining the distance that a standard needle will penetrate into it under a standard weight and in a standard interval of time. The distance that the needle penetrates is called the penetration of the sample. There are three types of apparatus all depending on the same principle, that of a needle penetrating, that have been described. The first apparatus was devised by Prof. H. C. Bowen in 1888 and is patented (Patent No. 404074). It is also described by Mr. Richardson in his report to the Engineer Commissioner for the year ending June 30, 1891, page 106. The author describes still another sort of apparatus in the report of the Operations of the Engineer Department of the District of Columbia for the year ending June 30, 1898. This apparatus has been found very convenient for experimental work, but being rather cumbersome to have in paving yards, etc., a simpler apparatus was devised which answers all purposes, even experimental work. The latter is shown in the accompanying Figs. 3, 4, and 5.

FIG. 3.

In Fig. 3 is shown the No. 2 needle *A* inserted in a short brass rod, which is held in an aluminium rod (*C*) by the binding screw *B*. The aluminium is secured in a framework so

weighed and balanced that when it is supported on the point of the needle *A* the framework and rod will stand in an upright position, allowing the needle to penetrate perpendicularly without the aid of a support. The frame, aluminium rod, and needle weigh 50 grams; additional weight, when desired, is placed on the bottom of the frame at *W*. In Figs. 4 and 5

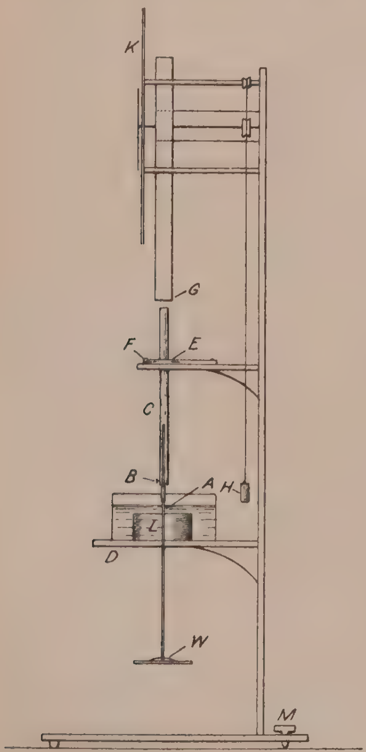


FIG. 4.

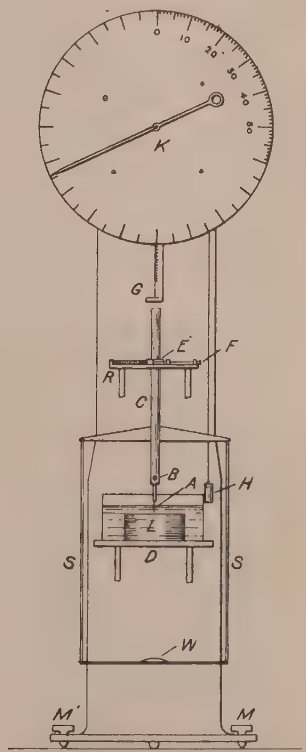


FIG. 5.

are shown the side and front views of the entire apparatus put together and ready for making a penetration. *D* is a shelf for the sample. *E* is a clamp to hold the aluminium rod *C* until it is desired to make the test. *F* is a button which when pressed opens clamp *E*. By turning this button while the clamp is being held

open, it will lock and keep the clamp from closing until unlocked. The device to measure the distance penetrated by the needle consists of a rack, the foot of which is *G*. The movement of this rack up or down turns a pinion to which is attached the hand which indicates on the dial *K* the distance moved by the rack. One division of the dial corresponds to a movement of the rack of one one-hundredth of a centimeter. *H* is a weight hung by a coarse thread which winds on a drum on the axle of the spindle and counterbalances the rack so that the rack can be raised or lowered by moving this counterweight *H* up or down. *L* is the tin box containing the sample to be tested, which is covered with water in a crystallized dish, thus keeping its temperature constant. *M M* are leveling screws. Fig. 6 represents a clock movement having a 10-inch pendulum attached to the wall to one side of the machine, used for timing the test. Make a mark (*P*) on the wall just at the extremity of the swing of the pendulum. A double swing of this pendulum—that is, from the time it leaves *P* until it returns—is one second.

FIG. 6.

To make the penetration test the samples of asphalt cement contained in circular tins, along with the glass dish, are placed in a receptacle containing at least five inches of water, which should have been previously brought to the temperature at which it is desirous to make the test. While the samples are under the water it should be stirred every few minutes, best with a thermometer, and the temperature kept constant when necessary by the addition of hot or cold water as the case may require. The samples should remain under the water at least fifteen minutes, and in cases where their temperature is not near that at which the test is to be made they should be left in possibly half an hour. After the samples have remained in the water a sufficient time to have attained its temperature they are ready to be penetrated.

One of the samples is now placed in a glass dish and removed in it, covered with as much water at the standard temperature as is convenient without spilling. The glass cup containing the sample is placed on shelf *D* under *C*, as shown in Figs. 4 and 5.

Insert brass rod with needle into C, and secure by tightening binding screw B. Lower C until the point of needle very nearly touches surface, then, by grasping the frame with two hands at S and S' (Fig. 5), cautiously pull down until needle is just in contact with surface of sample. This can be best seen by having a light so situated that looking through the sides of the glass cup the needle will be seen reflected in the surface of the sample. After thus setting the needle, raise counterweight slowly until the foot of rack G rests on the head of rod C; note reading of the dial. Place thumb of right hand on R and press button F with forefinger, thus opening clamp. Hold open for the desired time and then allow it to close. Raise counterweight H as before until foot of rack rests on rod C. The difference between the former reading of the dial and the present is the distance penetrated by the needle, or the penetration of the sample. Raise rack, loosen binding screw B, raise rod through clamp, leaving the needle sticking in sample. Remove needle from sample, clean well by passing through a dry cloth, replace needle in C, and the machine is ready for another test.

The needle which I have adopted as a standard for penetrating is a No. 2, manufactured by R. J. Roberts, Redditch, England. All the needles, however, obtained in a package cannot be used for penetrating, as they vary somewhat in shape, and only those are selected which give a penetration corresponding to a standard needle. The standards that I have adopted for this machine are: At 32° F. or lower, the distance in one-hundredths of a centimeter that a No. 2 needle will penetrate into the sample in one minute of time when weighted with 200 grams. For tests made at a temperature of 77° F., the distance in one-hundredths of a centimeter that a No. 2 needle will penetrate into the sample in five seconds of time when weighted with 100 grams. For tests made at a temperature of 100° F. or above, the distance in one-hundredths of a centimeter that a No. 2 needle will penetrate in five seconds of time weighted with 50 grams.

The following is a table giving the penetration and ductility of three classes of asphalt cement, which I have designated as A, B and C:

	A.	B.	C.
Penetration at 32° F.	10	13	25
Penetration at 77° F.	55	47	45
Penetration at 100° F.	150	110	75
Penetration at 115° F.	350	220	120
Ductility at 77° F.	300	75	20

It has been found from practical experience that it is not safe to use an asphalt that is more susceptible to changes in temperature than sample A, given in the table, for if it were more susceptible than this, and made to a softness to give it sufficient ductility at low temperatures, it would be too soft for use at high temperatures. The average paving cement gives penetrations such as represented by B in the table. Sample C in the table represents the least susceptible cement which I have found on the market. This non-susceptibility to change in temperature would be of great advantage if it were not for the fact that the cement is lacking in ductility. There is a law which I have found that invariably applies to the properties of asphalt cements, that is, that the less susceptible cement is to change in temperature the less ductile it is at normal temperatures, and inversely the more susceptible the more ductile is the cement.

Fluidity.—As has been mentioned before, the more ductile an asphalt cement the more perfect a fluid, and the more cementitious. The fluidity is judged from the amount of ductility, which is tested as has been previously described.

Heat Test.—To ascertain whether the asphaltic cement will be injured by the heating which it must undergo during the process of manufacture into the pavement. The quantity of asphaltic cement is 50 grams. It is advisable to accurately weigh the quantity of cement used for this test before it is heated, so that any loss may be determined by ascertaining its weight after having been heated. The receptacle used to contain the asphalt cement while heating is a tin box, $2\frac{1}{2}$ inches in diameter by $\frac{4}{5}$ of an inch in depth, having a flat bottom. I have chosen this receptacle as it is a standard size tin box that can be bought on the market, in this way the cost of the box being so small it can be discarded after each test. While the sample is being heated it should be stirred from time to time so as to break up any skin that may

form on its surface which would protect it from evaporation and oxidation. After the asphalt cement has been heated as above described it is allowed to cool, and its consistency by penetration is again taken at 77° F. The difference between the penetration before heating and that after heating is the amount of hardening which the sample has undergone.

It is to be hoped in the near future that an improved modification of this test can be adopted on the following lines: As there is considerable variation in the degree of temperature at which different asphaltic cements become sufficiently liquid to mix with the mineral ingredients, this test would be more practical if the cements were tested at the temperatures at which it is practical to work them. As for example: One cement may be so fluid at 250° as to be capable of mixing just as well as another one at 300°. In the testing of these two cements it would only be necessary to test the one at 250° and the other at 300°. This modification in the test will be adopted as soon as an apparatus has been perfected for determining the viscosity of molten asphalt cements at high temperatures.

I have found that all the desirable asphaltic cements on the market at the present time are capable of meeting the following requirements when tested as above described: They will not lose by volatilization over 5 per cent. by weight, and will not be hardened more than 50 per cent. by this heating.

Change Due to Aging.—All bitumens undergo a more or less rapid change with aging that appears to be due to two or possibly more causes. Two distinct changes manifest themselves. One is the surface hardening, which is likely due to oxidation, and possibly to the volatilization of some light oils. It begins at the surface and gradually extends into the bitumen. The other is a hardening of the entire mass, evidently due to condensation of molecules. Both these changes take place in all bitumens, but one or the other may predominate. The former is much the less objectionable, as it makes but slow progress into the mass.

The best method for determining the aging of the asphaltic cement, although it is somewhat slow, is as follows: The asphaltic cement is placed in a sample tin, and its consistency by penetration determined at 77° F. This sample is then put away in some place

protected from the dust, but without a cover, so as to have free access of the air. At the end of two weeks or a month the consistency of the sample is again tested at the same temperature, when it is again put away. This testing every few weeks is kept up until the sample is appreciably hardened. A slanting cut is then made into it with a sharp, thin knife, laying over the upper piece, thus exposing a gradual descent from the surface into the interior of the cement. Penetrations are now taken down the side of this cut, beginning at the surface. In this way the increase in hardness of the surface and the interior over its original consistency is determined also, the hardening of the surface over the interior and the depth that the surface hardening has entered the sample.

Another method which I have lately employed, and which is somewhat more rapid, is by taking an asphaltic cement of known consistency by penetration at 77° F., and spreading 50 grams of it on a piece of plate glass 9 x 9 inches square. The plate thus coated is placed away in a dust-proof drawer. At the end of two weeks or a month the coating is scraped from the plate by a steel straight-edge, and molded into a suitable receptacle at the lowest temperature possible. The consistency by penetration is again taken, and the increase in hardness of the asphaltic cement indicates its rapidity of aging. This method, of course, does not differentiate between the two hardenings.

As all asphaltic cements are not of the same degree of purity, it is necessary for comparison that the tests for their physical properties be made on a basis of the pure bitumen. For this reason it is necessary to ascertain the relation existing in the various tests made on the asphaltic cement, and the pure bitumen it contains. After such a ratio has once been established, test can be made on the asphaltic cement, and allowance made for the impurities other than bitumen. Due allowance can then be made in comparing the results of physical determinations on cements of different purities.

The pure bitumen is obtained from an asphalt or asphaltic cement by extracting with carbon disulphide and evaporating off the solvent. The procedure that I have found to give the best results is as follows: Sufficient of the asphalt or asphaltic cement

to give 30 grams of pure bitumen is placed in a large Erlenmeyer flask. Between 300 and 400 c.c. of carbon disulphide is added, the flask corked and then shaken from time to time until none of the asphalt is seen adhering to the sides or bottom, after which the flask is set aside and allowed to stand for 24 hours. The carbon disulphide is then decanted off carefully from the residue into a second flask. The residue is again treated with 200 or 300 c.c. of the solvent and shaken as before. After the solutions in the two flasks have been allowed to subside for 24 hours, the contents are carefully decanted off on to an asbestos filter, passing the contents of the second flask through the filter first. The solvent containing the bitumen is then distilled in a flask until just sufficient remains to have the contents liquid. It is then poured into a flat evaporating dish and further heated on the steam-bath, stirring from time to time, until the greater part of the carbon disulphide is evaporated. About $\frac{1}{2}$ c.c. of water is next incorporated into the residue of bitumen and the heating continued over a burner until all foaming ceases, after which it is kept at 300° F. for ten minutes. While heating over the burner the bitumen should be stirred constantly with a thermometer and care exercised that the temperature is kept constant at 300° F. It is doubtful whether in all cases the last traces of carbon disulphide are removed, even by this method, and it is also likely that the pure bitumen obtained in this way is often slightly harder than that contained in the original asphalt or cement; but its physical properties, as far as ductility and susceptibility to change in temperature go, will be relatively the same, and a sufficiently close approximation can be made of the consistency of the bitumen in the original sample to answer all practical purposes. As the removal of the last traces of carbon disulphide is very difficult, and a soft bitumen is liable to be hardened in so doing, I make it a practice, wherever it is possible, to extract the bitumen from an asphalt before it has been softened into the paving cement. In this way I find it easier to remove the last traces of solvent from this hard bitumen, and at the same time with relatively less hardening. This bitumen from the asphalt is then fluxed into a paving cement by adding to it an amount of flux equivalent to that used in making the paving cement from the asphalt. It

is fortunate that nearly all the asphalts met with in commerce that are not pure bitumen are of a hard nature, so that the above method is applicable in practically all cases. This of course does not apply to bituminous rock, and the only way possible to estimate their quality is by examining the extracted bitumen, which is done as just described. It is well to note here that in cases where the bitumen hardens materially in the removal of the solvent, such a bitumen will be rejected by hardening too much in the heat test.

I have found that it is not safe to estimate the ratio between an asphaltic cement and the pure bitumen it contains on theoretical reasoning, as the impurities in different asphalts produce different physical effects. For instance: A Trinidad asphalt cement which contains 36 per cent. of impurities other than bitumen has a penetration of 40. The pure bitumen of the cement has a penetration of 58. A Bermudez asphalt cement containing 5 per cent. of impurities, and having a penetration of 50, contains a bitumen of 56 penetration. In the first case we have impurities of 36 per cent., making a difference of 18 in the penetration between the asphalt cement and the pure bitumen it contains, while in the latter case 5 per cent. impurities makes a difference of 6 penetration between the two.

Chemical Tests.—There has been but little done that is of practical value in chemical tests on bitumen, and there is so much confusion in what has been done that it is difficult for anyone without considerable experience and knowledge of the subject to distinguish what is of practical value. One source of confusion in the examination of asphalts by chemical means results from the careless statement of methods of analysis given in some of our standard text-books. An example of this is found in Sadtler's *Hand-book of Industrial Organic Chemistry*, page 42. He states: "When on the other hand the asphalt is to be considered with reference to its value for asphalt paving purposes, it is necessary to examine into the quality of the bitumen. For this purpose the total bitumen (amount soluble in carbon disulphide), organic not bitumen, and ash are first determined. Then the amount soluble in petroleum naphtha (so-called petrolene) is ascertained. The difference between this and the total bitumen

is called asphaltene. . . . Instead of petroleum naphtha and carbon disulphide, acetone and chloroform may be used with advantage for extractions." While there is but slight difference between the results obtained from carbon disulphide and those obtained by chloroform extraction, yet there is no similarity at all in the solvent power of acetone and petroleum naphtha, and for this reason the results are not comparable. By the exercise of a little care in the compiling of such books a great benefit would result to those who have not the time to go deeply into the subject.

An illustration of the confusion resulting from the introduction of acetone as a solvent is found in the second edition of Stillman's *Engineering Chemistry*, page 438. He here gives a method of analysis by which the asphalt is first extracted with acetone and then by chloroform as recommended by Sadtler, and calls the material, extracted with the acetone, petrolene. He then goes on to give the method of L. A. Linton (J. A. C. S. 18, 375), in which the asphalt is first extracted by petroleum ether, then turpentine, and afterward with chloroform. He here speaks of the bitumen that has been extracted with petroleum ether as petrolene. If the bitumen soluble in petroleum ether is to be called petrolene, surely the same author should not make the mistake and call a totally different set of hydrocarbons, that are dissolved out by acetone, by the same name. There is yet another class of bodies derived from asphalt that are known by the name of petrolene. In 1837 Boussingalt subjected an asphalt to the process of distillation, naming the liquid which distilled off petrolene, and the residue left in the retort asphaltene. Dr. H. Enderman subjects asphalts to the Boussingalt process, applying his terms to the distillate and residue which he obtains. Here are three distinct methods of separation applied to asphalts, each separation producing totally different complexed compounds, yet the same terms, petrolene and asphaltene, are applied to the products obtained in each separation. This leads to so much ambiguity in the subject that I can see no way to right things but by the abandonment of the names petrolene and asphaltene. I would advise the use of terms naphtha soluble, acetone soluble, etc., for the products extracted with these solvents.

Still another error into which people are led by some literature

on the subject, when they first take up the study of asphalt, is the belief that petrolene and asphaltene are each a definite chemical compound. The petrolene and asphaltene obtained in any of the processes mentioned are not simply compounds, but complexed mixtures of many chemical compounds, and petrolenes and asphaltenes derived from different asphalts are totally different from each other in their composition, and for this reason such determinations on asphalts can bear no relation whatever to their physical properties or suitability for paving. I cannot too highly recommend to all who are at all confused about the nomenclature and analysis of asphalts that they read the most excellent chapter in the *Bulletin of the University of Texas*, No. 15 ("Coal Lignite and Asphalt Rocks"), by Henry W. Harper. He discusses most comprehensively the ambiguity of the methods and nomenclature of this subject. His results on the bromine absorption applied to different so-called petrolenes and asphaltenes are evidence sufficient that these complexed compounds differ in composition in every asphalt.

Bitumen Soluble in Carbon Disulphide.—It is usually considered that all the cementing material of an asphaltic cement is soluble in carbon disulphide, but there is good ground for the belief that this is only approximately true and that the carbon disulphide in some cases dissolves materials that play no more part in the cementing than so much sand, while in others it leaves part of the cementing material undissolved. As, however, we have no means at the present time of determining the absolute quantity of cementing material in an asphaltic cement, and as the quantity soluble in carbon disulphide is as close an approximation as any, and this solvent is more generally used than any other, I advise adhering to its use. It is for this reason that the use of chloroform or turpentine, as advised by some analysts, because it dissolves a little more from asphalt than does carbon disulphide, is not only unnecessary, but not advisable. There are numerous methods applied to the extraction of asphalt with carbon disulphide, the important ones of which can be found in Allen's *Commercial Organic Analysis*, vol. ii., part ii. Most of these methods are based on separating the insoluble matter from the soluble matter by filtration, and no correction is made for

finely divided material, other than bitumen, which passes through the filter. From investigation I find that more or less finely divided mineral matter and organic matter not bitumen passes through the filter. It is claimed by some that this mineral matter is all in chemical combination with the bitumen, but I often find in the examination of paving mixtures that the finely ground limestone which is used in the mixture is found in the filtrate. I also find that the filtrate from some asphalts invariably contains finely divided organic matter which will subside on standing. It is seen from the above that for a method to be the most accurate, filtration cannot be depended on, for even though the filtrate be evaporated off and burnt, in which a correction for the mineral residue passing the filter is made, the insoluble organic matter which has passed the filter is burnt off and considered as bitumen. It is for this reason that a method in which a long subsidence is used is the most preferable. The following is a method which I find, from long experience, gives the most accurate results: The asphalt, or like substance, is spread in a thin layer in a suitable dish (nickel or iron will do) and kept at a temperature of 225° F. until it practically stops losing in weight. The greater part and in some cases all the water and some light oils are expelled in this way. From 2 to 10 grams (depending on its richness in bitumen) of this substance is weighed in a large-sized test-tube (8 inches long by 1 inch diameter), the tare of which has been previously ascertained. The tube containing the substance is then filled to within 1½ inches of the top with carbon disulphide and allowed to stand for a few minutes. Then the tube is tightly corked with a good sound cork. It is then shaken vigorously until no asphalt can be seen adhering to the bottom. Care should be taken while shaking to keep one finger on the cork to prevent its being blown out. The tube should then be put away, still corked, in an upright position and not disturbed in the slightest way for two days, after which the carbon disulphide is decanted off into a second tared tube. As much of the solvent should be poured off as is possible without losing any of the residue. The first tube is again filled with fresh carbon disulphide and shaken as before and put away for two more days. The second tube is also corked and put away in an upright position. At the end of two days the

contents of these two tubes are decanted off on to a weighed Gooch crucible fitted with an asbestos filter, the contents of the second tube being passed through the filter first. The residue in the second tube is then treated with about 2 c.c. of carbon disulphide, care being exercised to disturb it as little as possible, the treatment merely being to remove the small portion of solvent containing bitumen. A Gooch crucible is then washed with clean carbon disulphide until the filtrate is colorless. The crucible and the two tubes are then dried at 225° F., and weighed. The filtrate containing the bitumen is evaporated and the bituminous residue burnt, and the weight of the ash added to that left in the two tubes and Gooch crucible. The sum of these weights deducted from the weight of the substance taken gives the weight of the bitumen extracted.

The practice of some analysts to first extract the bitumen soluble in naphtha or other solvent, and then extract the remaining bitumen with carbon disulphide, is not safe with some asphalts, as some of this residual bitumen is apt to be rendered insoluble, possibly by oxidation while driving out the first solvent.

Bitumen Soluble in Naphtha.—The amount of bitumen soluble in naphtha, as has been before explained, is of no value excepting as generally indicating within broad limits the degree of hardness of an asphalt. The only advantage of this test is that it requires no other apparatus other than is found in everychemical laboratory, and if standard methods could be adopted for its use, making a determination for the bromine absorbed on the naphtha-soluble bitumen and the bitumen insoluble in naphtha, the test might be made of interest in the examination of asphalts. The statement often made that an asphalt which contains more than 30 per cent. of asphaltene (bitumen insoluble in naphtha) is unsuitable for paving is not founded on facts. It does not matter how much asphaltene an asphalt contains so long as it can be softened into a proper cement by the addition of a suitable flux. I have, myself, seen asphalts which contained over 50 per cent. of asphaltene made into paving cements, and excellent pavements made therewith. It is also occasionally seen stated that the suitability of an asphalt cement for paving can be determined by examining the petrolene which it contains. This has been denied by Professor

Peckham, who insists "that the bitumen of Trinidad pitch consists of asphaltene dissolved in petrolene, and that its cementitiousness is just as much due to one as the other. Sand cannot be cemented with either petrolene or asphaltene alone, neither can wood be cemented with either water or glue alone. The cementitiousness depends upon the amount and quality of the bitumen present." I agree heartily with this remark of Professor Peckham in all respects but one, and that is: I would say that an asphalt consists of asphaltene in a more or less perfect solution of petrolene, as I find that in nearly all cases that while a portion of the asphaltene is evidently in solution in the petrolene there is another portion which exists in what might be called a colloidal solution.

I have adopted the following method for the determination of the bitumen soluble in naphtha: A quantity of the asphaltic material sufficient to contain about 1 gram of bitumen is weighed into a 3-ounce Erlenmeyer flask. This is treated with 50 c.c. of naphtha. The flask is then corked and shaken several times during the first two or three hours, when it is placed away for twenty-four hours. The solution is then carefully decanted on to a weighed Gooch crucible with an asbestos filter. This decanting can be done very close, and it does not matter if some of the residue does flow into the crucible. The residue is then treated with consecutive portions of naphtha until the filtrate becomes practically colorless. The sum of the weights of the residue in the flask and in the crucible is deducted from the weight of the substance taken, and gives the amount of the bitumen soluble in the naphtha.

As the solvent power of different naphthas varies, it is very essential that the same naphtha be used each time for making this determination, and it is also necessary to make the extraction at the same temperature each time, as the higher the temperature the more solvent action is exerted by the naphtha. It is for this reason that I do not advise the use of the Soxhlet or other forms of extracting apparatus that use return condensers, as it is next to impossible to have the extracting solvent at the same temperature for each extraction. If the extracting is done by the method which I have described, the naphtha will be the temperature of the laboratory, which is usually quite constant. The naphtha

which I use for extracting distils between 60° and 80° F., and has a gravity at 60° F., closely approximating 0.680.

Action of Water on Pavements.—The action of water on asphalt pavements has, in the past, received little or no consideration from engineers. This question, I believe, is a very important one, and the asphalt should be examined to determine whether or not it is attacked by water or moist air. There are many failures resulting from this action that have been blamed to other causes in the past, and a more thorough study of this subject is much to be desired.

A simple method which I have adopted to ascertain the rapidity of the action of water is by coating a piece of glass with the asphalt paving cement, and partly immersing this coated glass in water. The coating is examined at intervals, and the time noted when the first discoloration or action is noticed on the surface of the sample.

Another method which I sometimes use is by molding two 1-inch cubes of the paving mixture under a fixed pressure. This mixture is made with a standard sand, and the same amount of bitumen used each time. One cube is immersed in water while the other is kept in air. These cubes are examined at the end of a month or two, and any increase in the volume or softening of the one in water over the one kept in air is noted.

The tests which I have given in this paper are only applicable to asphaltic cements which are ready to be combined with the mineral matter in the making of sheet asphalt pavements. The examination of asphaltic cements for asphalt block pavements is somewhat different.

DISCUSSION.

CLIFFORD RICHARDSON.—While Mr. Dow's paper is, in many respects, of considerable interest, it appears to be open to criticism in certain directions. Mr. Richardson.

In the first place, I believe that denominating the hydrocarbons and their derivatives, which are extracted by naphtha as petrolene and those soluble in bisulphide of carbon and similar solvents as asphaltene, is open to serious criticism, as the materials extracted are in no sense homogeneous. I prefer the use of the terms "petrolenes" and "asphaltenes," as representing classes of substances soluble in these liquids, without any attempt to designate them as any particular substance. When used in this way the terms admit of no misunderstanding or confusion, especially if the specific gravity of the naphtha is stated and the method in which it is used is carefully described, more especially the temperature at which it is employed.

In regard to Mr. Dow's determination of ductility, I would call attention to the fact that the rapidity or stress under which the prisms were drawn out would make a very decided difference in the ductility of any asphalt cement and that the conditions employed in his test should also be definitely stated.

In regard to the action of water on asphalt, I believe that laboratory experiments form no basis for drawing conclusions as to the results which would occur in the pavement. There is no question but that when an asphalt, such as that from Trinidad pitch lake, is exposed to the continued action of water it deteriorates to a certain degree after a considerable length of time. As it is used in an asphalt surface for pavements, such action does not take place, owing to the fact that if the mineral aggregate of the surface is properly graded, the latter is so compacted that water is unable to penetrate and act upon the cement. Where the mineral aggregate is not properly graded and porous, such action may take place, but in well-constructed surfaces, such as that on Fifth Avenue in

Mr. Richardson. New York, no deterioration has been noticed in the course of seven years. In the field with which Mr. Dow is more particularly acquainted, Washington, D. C., the sand used in the construction of the asphalt surface is not of such a character as to render it possible to make most desirable mixture. This, combined with the fact that the Portland cement base in use in Washington is very porous, as it consists of a 1–3–7 concrete, accounts for much of the deterioration noted in that city Under similar circumstances, in New Orleans, Detroit, and elsewhere, asphalts which are not attacked at all in the laboratory, under the conditions prescribed by Mr. Dow, have suffered equally with Trinidad lake asphalt. The remedy for any such action lies in the use of a suitable base and protection of the pavement from the continued action of water by proper drainage.

The presence of illuminating gas from leaky mains in itself is sufficient to destroy an asphalt surface, and much of the deterioration of such surfaces which is attributed to water is due to the combined action of gas and water, the action of either one being much increased by the presence of the other.

Practical experience has shown, in over eighty cities in the United States, that it is the lack of proper conditions under which the pavement is laid, rather than the asphalt itself which are at fault for the deterioration of such surfaces, and that the substitution of one asphalt for another will not accomplish the results which Mr. Dow's laboratory tests lead him to believe would be the case.

Mr. Cushman A. S. CUSHMAN.—I do not altogether agree with Mr. Dow in his opinion as to the effect of water upon asphalt pavement. While admitting that water has, to a slight extent, a deteriorating influence on bituminous pavement, I believe that its action on a well-laid pavement is small. The best proof of this is to be found in the numberless miles of asphalt pavement which has stood the test of years. In my opinion the special cases of unusual and rapid deterioration can be traced to the action of illuminating gas or other agent in connection with the water. I must also take exception to Mr. Dow's requirement under his heading number (5), viz.: "The pavement must not contain any material that is acted on by water," etc. Probably all bitumens

are slightly acted on by water. Some asphalts, as is well known, contain a small proportion (0.2 per cent. to 0.3 per cent.) of soluble salts, and yet it has never been proved that such a material is unsuitable for paving. On the contrary, many miles of streets are paved successfully with just such asphalt. I must also disagree with Mr. Dow as to water working into a pavement which is pliable under the passage of traffic. Brittle porous materials are more apt to absorb water than dense pliable ones, and in my opinion the life of a pavement depends more upon proper construction than upon the presence of a minute quality of soluble substances. Mr. Cushman.

CHARLES M. MILLS.—I should be pleased to have an expression of opinion as to the relative durability and efficiency for waterproofing underground of rock asphalt, lake asphalt, and of mastic into which rock asphalt enters as an ingredient. With the number of tunnels and rapid transit subways under construction and contemplated, the question of the proper materials to be selected for waterproofing is important. The resistance of the various materials to injury by the action of gas, liquids, sewer leakage, and oil used at street railway switches is an important element to consider where tunnels are built under the streets of a city. Mr. Mills.

MR. RICHARDSON.—As to the applicability of asphalt for waterproofing purposes, the best native bitumen will not give satisfactory results unless it be properly applied, in the same way that the best Portland cement might fail if improperly used. Bituminous waterproofing, when done with skill, is entirely satisfactory, as was evident from the complete success of such linings in the Queen Lane Reservoir at Philadelphia and numerous other places. In order to produce a satisfactory bond between concrete and a waterproof course, the concrete should be first painted with an asphaltic paint composed of asphalt dissolved in 62° Beaumé naphtha, as otherwise the bond might not be obtained. Asphalt waterproofing has proved entirely satisfactory in the subway in New York, and has been adopted for the subway in Philadelphia. Mr. Richardson.

A. W. DOW (by letter).—In answer to Mr. Richardson's comments on the portion of my paper relating to the action of water on asphalt, I would say that my conclusions are not drawn only from laboratory experiments, but from practical results observed in actual pavements. I have noticed that pavements made from Mr. Dow.

Mr. Dow. some asphalts are more readily acted upon by water than those made from others, and the difference is very distinct. It is from this condition in the pavement that the laboratory tests for the action of water on asphalt which I give in my paper, and to which Mr. Richardson objects so strongly, were instituted.

I agree with Mr. Richardson that the compactness of a pavement has considerable to do with the rapidity of the action of water upon it, but I notice that the most compact pavements made with asphalt that is readily attacked by water disintegrate much more rapidly than do the most porous pavements made with an asphalt that is not readily acted on by water, when they are both subjected to damp concrete. As regards that which Mr. Richardson says about the mineral aggregate which we use in Washington being not properly graded and porous: It is possible that Mr. Richardson does not remember the character of our mineral aggregate, for I have seen several reports made by him to the Barber Asphalt Paving Company, of Washington, D. C., complimenting them on the character of this aggregate.

I must deny what Mr. Richardson says about the porous condition of concrete, made 1–3–7, being partly responsible for the rotting of any pavements. Mr. Richardson is well acquainted with the fact that such a formula for concrete was not used prior to two years ago, and as yet we have not noticed any pavements, laid on such concrete, rotting. We have, however, pavements rotting from the action of water on concrete eight inches thick, and made 1–2–4½. My observations are not alone confined to Washington, but have extended over many cities.

Mr. Richardson admits that Trinidad asphalt is more readily attacked by water than any other known asphalt, when exposed to continuous action. It is a well-known fact that any concrete exerts a capillary action through its pores, and that if the subsoil is at all damp, moisture will be drawn up through the concrete. In many cases the subsoil is continually wet, and in such cases the pavement in contact with the concrete is under the continued action of water. But the subsoil is not the only conductor of water. It may enter in various ways from the surface.

I agree with Mr. Richardson that one of the remedies for such action is in the construction of a suitable base. I have

examined many asphalt pavements that have been laid over other old smooth pavements, and have never found any that showed the slightest action of water unless there was a railroad track or some such break in the pavement which would allow water to enter from the surface. I believe that on streets where there are no railroad tracks or other like cuts through the pavement, a properly constructed base would be practically a remedy for the action of water, which I find so detrimental to pavements. One form of base which I would suggest would be a layer of broken stone on the subsoil, 4 to 6 inches deep, depending upon the character of the soil. On this lay the regular concrete base for the pavement. Such a course of broken stone would prevent any moisture coming in contact with the bottom of the concrete base, and thus prevent it drawing it up to the asphalt surface. If there were any hydrostatic pressure such a subsoil could be effectually kept dry by sub-drainage under the gutters. Mr. Dow.

Illuminating gas has a softening action on asphalt pavements, and with water present a more rapid disintegration takes place, but it is a simple matter to determine whether a pavement is being acted on by gas, for it is very readily detected by the odor and by the extraction of gas in the laboratory. There are many cases, however, where I have observed pavements disintegrating from water action when there is no gas-main or pipes under the pavement.

In answer to Mr. Mills' inquiry as to the durability and efficiency of waterproofing with different asphalts: There is very little known about the subject of waterproofing with asphalt at the present time, and I believe it should be treated very cautiously. Whipple and Jackson, in examining asphalts for waterproofing a Brooklyn reservoir, found that all asphalts were acted on, to a certain extent, by water; some much more than others. It is well, in selecting an asphalt for such waterproofing, that one be selected that is but slightly acted on by water, and I would advise putting the asphalt on in heavy coats, preferably with asphalt paper.

SOUNDNESS TESTS OF PORTLAND CEMENT.

By W. P. Taylor.

For all purposes of construction a good cement must possess two essential qualities, strength and durability, and of the two the second is by far the more important. Few if any cements, provided they are well handled, will fail because of lack of strength alone, so it may be generally stated that the chief purpose of the testing of cement is to determine its permanency, and yet less is probably known concerning the various tests for soundness than any of the others, and certainly no test is more frequently abused.

The most important factor operating in a cement to cause unsoundness is an excess of lime, either free or loosely combined, which has not had opportunity to become sufficiently hydrated. The presence of this lime may be due to incorrect proportioning, to underburning, to lack of seasoning, or to coarseness of grinding, which prevents perfect hydration. An excess of alkalies is also sometimes responsible for disintegration, while the presence of sulphate of lime acts in the opposite direction and tends to make good an otherwise unsound cement, at least as far as laboratory tests are concerned.

For determining soundness in Portland cements three general forms of tests have been used: (1) Direct measurement of expansion. (2) Normal tests. (3) Accelerated tests.

In this country direct measurement of expansion has never been extensively used, although abroad it has been, and is even still occasionally employed as a test for the determination of durability, in spite of the fact that it has been shown that a cement may give a high expansion as a whole and yet be entirely free from any tendency to disintegration. The old "lamp chimney" test is the only form of this determination ever employed at present, and its use is rapidly dying out as the properties of cement are becoming better known.

Tests of soundness are therefore ordinarily limited to the normal and accelerated tests on pats, cakes, and briquettes of neat cement. The normal test in air and water is unquestionably

the only perfectly fair method of determining the permanency of a cement, yet in practice the element of time usually makes imperative the use of some form of accelerated test, which is supposed to hasten any expansive action and to cause any possible failure of the material in a few hours, instead of in the weeks or months usually required for a normal pat to develop unsoundness.

The most common forms of accelerated test used are:

1. The boiling test.
2. The steam test.
3. The hot water test.
4. The flame test.
5. The kiln test.
6. Tests under pressure of steam, hot air or hot water.
7. Strength tests of briquettes kept under some of these conditions compared with normal briquettes.

Of these tests the first three—those in steam, hot water, and boiling water—are by far the most important, not necessarily on account of their accuracy or reliability, but because of their almost universal use.

The Philadelphia Testing Laboratories have, in the last few years, had opportunity to investigate very thoroughly the action of cements under accelerated tests, and, owing to their rather unusual facilities regarding the quantity and the variety of tests made, have accumulated some very interesting data, some of which will be given here. The records of the laboratory not only include a full series of physical tests, but also chemical analyses, tests of the strength of the concrete as used, and also records of the actual condition of the materials as found in the work.

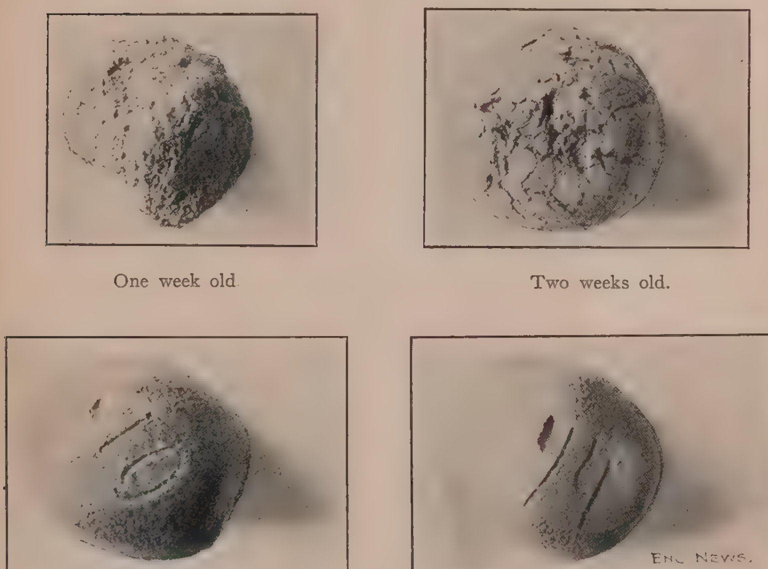
In regular routine the accelerated test is made in boiling water on cakes of cement, in the form of a small egg about one inch on its long diameter, which are kept in moist air for twenty-four hours, then placed in cold water which is gradually raised to the boiling-point and maintained at that temperature for three hours, after which the specimens are removed and examined. Tests in steam, hot water, and in combinations of these treatments, for varying lengths of time and for varying ages of the specimens, are also frequently made for purposes of comparison and for general investigation.

The condition in a cement most affecting the result of an accelerated test is its age or the amount of seasoning it has undergone. Every cement, no matter how well proportioned and burned, will contain at least a small amount of free or loosely combined lime, which will usually cause unsoundness if used or tested at once. This lime, however, will hydrate in a very short time on exposure to the air, thus rendering it inert and preventing any expansive action. It will, therefore, be found in a large majority of cases that if a cement failing in the accelerated tests be stored for two or three weeks, this unsoundness will disappear, and the cement pass the tests with ease. A typical case of this is shown in Table I. It will be noticed in this case that the cement has been made thoroughly sound by a seasoning of five weeks. The early strength values of the neat tests are also seen to fall off decidedly, while the sand tests generally show a slight increase.

TABLE I.—EFFECT OF AGE OF CEMENT ON RESULTS OF BOILING TEST.

Age of cement when tested.	Tensile strength. Neat. 1 day.	Neat. 7 days.	Neat. 28 days.	1 : 3 sand. 7 days.	1 : 3 sand. 28 days.	Normal pat tests. 28 days in air.	Normal pat tests. 28 days in water.	Boiling test.
1 week	550	765	762	171	225	Curled and soft.	Slightly checked.	Partly disintegrated.
2 weeks	548	767	771	170	246	Slightly curled.	Slightly curled.	Checked and cracked.
3 "	492	718	763	182	244	"O. K."	"O. K."	Slightly checked.
5 "	427	692	747	183	249	"O. K."	"O. K."	Sound.

Coarseness of grinding is also a frequent cause of unsoundness for the reason that the larger particles are not readily susceptible to hydration, and contain for a long period of time expansive elements, which very rapidly develop a disintegrating action when treated in the accelerated tests. Table II. shows a typical instance of this action.



One week old.

Two weeks old.

Three weeks old.

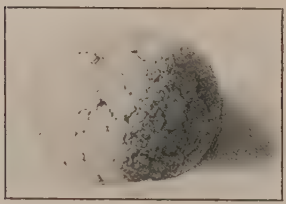
Five weeks old.

FIG. 1.—Cakes of cement of different ages subjected to the boiling test.* (Table I.)

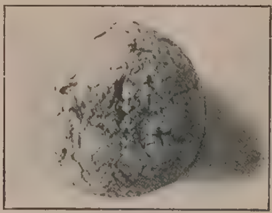
TABLE II.—EFFECT OF FINENESS OF GRINDING ON RESULTS OF BOILING TEST.

Condition of cement.	Fineness.			Boiling test.
	No. 50.	No. 100.	No. 200.	
As received	0.5	13.2	33.4	Badly checked and cracked.
Same sifted	0.0	0.0	0.0	Sound.
Same ground	0.0	0.6	3.0	Checked and cracked.
Ground cement, one week later .	0.0	0.6	3.0	Very slightly checked.
" " two weeks later .	0.0	0.6	3.0	Sound.
As received, two weeks later . .	0.5	13.2	33.4	Checked and cracked.

* Acknowledgment is made to the *Engineering News* for the cuts used in this paper.

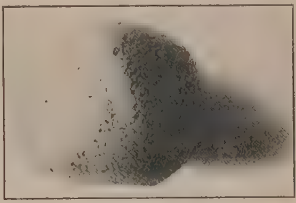


No. 1. Cement as received (tested two weeks later than No. 3).



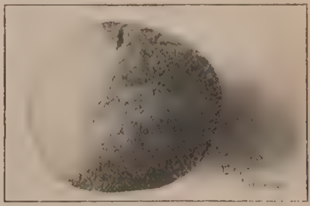
No. 2. Cement finely ground (tested same time as No. 3).

No. 3. Cement as received (very coarse).



No. 4. Cement finely ground (tested one week later than No. 3).

No. 5. Cement finely ground (tested two weeks later than No. 3).



No. 6. Cement as received (sifted to pass No. 200 sieve).

FIG. 2.—Cakes of cement of different fineness and varying age subjected to boiling test. (Table II.)

The objection most frequently made to accelerated tests, and particularly to the boiling test, is the great variance in the methods used; different laboratories using different forms of test piece, and different periods of time before the test and for its duration. The variance in the results obtained under these several methods is, however, far less than it is generally supposed. The form of the test piece has practically little or no influence on the results, whether it be a cake, a ball, a wedge, or a pat, if the duration of test be sufficient. In a large number of tests made recently by the writer to determine how the results obtained from test pieces in the forms of pats and eggs varied, no differences were observed except in one instance, where the pat seemed to show a slight checking, while the egg remained sound. The only advantage that the pat has over the other form is that curvature can be readily ascertained, but a mere curvature of the pat should not be considered as a failure in boiling unless accompanied by checking. The requirement sometimes given that a pat should not leave the glass in boiling is not reasonable, as a small amount of expansion may be naturally considered normal.

The greatest difference in the methods of conducting the boiling test probably lies in the duration of the treatment, different specifications requiring the test to be made from one to as high as forty-eight hours. To determine the effect of different lengths of treatment a large number of tests on different cements were made and the time at which failure occurred was observed. In these tests it was found that of those samples which did not pass the test, 22 per cent. failed in the first half hour, 57 per cent. failed in the first hour, 85 per cent. failed in two hours, 96 per cent. in three hours, and 99 per cent. in four hours. Only 1 per cent. of the tests that failed developed this action in over four hours, although many of them were carried up to twenty-four, and a few to forty-eight hours; thus showing generally that a test piece of cement standing three or four hours of boiling will almost invariably stand a much greater length of time, and also that at least three or four hours should always be allowed for the test.

The time allowed for the specimen to harden before it is tested may cause considerable differences in the results, but if it always be given time to fully develop hard set the differences

will be slight. Pats of cement allowed more than about twelve hours to harden will, if unsound, fail when tested by boiling at almost any time in the future. The writer has seen normal pats as old as six months and apparently perfectly sound, which when put through the boiling test showed a failure almost identical to that obtained on the original test six months previously. If, however, the specimen is tested before it has fully hardened, the differences obtained in the results are often very decided, and, curiously enough, may operate in either direction—that is to say, a pat of cement may fail more readily when one hour old than when twenty-four hours old, or a one-hour pat may pass the test, while the twenty-four-hour pat may fail. The reason for this action is by no means apparent, but it may be observed that in the ordinary case of the cement high in free lime from underburning the failure will usually be more marked in the fresher specimens, and that in the more infrequent case of the cement normally burned, but high in lime by reason of poor proportioning, the failure is often more marked in the older specimens. It would seem in this case that the cement was sufficiently strong to retain coherence in the test although insufficiently hardened, and that in this condition the lime was capable of becoming hydrated without causing disintegration.

For the same reasons a treatment of the specimen in a bath of steam before immersion in boiling water is generally less severe than if the specimen be boiled without this treatment, particularly so if the test be made before the test piece has become fully hardened.

It is also evident from the foregoing that tests made in steam alone without subsequent immersion in hot or boiling water may often give rise to erroneous conclusions regarding the results, especially if the specimens be tested soon after making.

We now come to the very important question of the relation of the boiling tests to the other tests for soundness and strength as made in the laboratory. No one who has had much experience with the boiling tests questions that, although it is by no means infallible, the results obtained from it are generally corroborated by either the tensile tests or the normal tests for soundness. The writer has recently compiled some data in regard to this point

covering over a thousand tests on many varieties of cement with the following results:

Of all samples failing to pass the boiling test, 34 per cent. of them developed checking or curvature in the normal pats—or a loss of strength in less than twenty-eight days. Of those samples that failed in the boiling test but remained sound at twenty-eight days, 3 per cent. of the normal pats showed checking or abnormal curvature in two months, 7 per cent. in three months, 10 per cent. in four months, 26 per cent. in six months, and 48 per cent. in one year; and of these same samples, 37 per cent. showed a falling off in tensile strength in two months, 39 per cent. in three months, 52 per cent. in four months, 63 per cent. in six months, and 71 per cent. in one year. Or, taking all these together, of all the samples that failed in the boiling test, 86 per cent. of them gave evidence in less than a year's time of possessing some injurious quality.

On the other hand, of those cements passing the boiling test, but one-half of 1 per cent. gave signs of failure in the normal pat tests, and but 13 per cent. showed a falling off in strength in a year's time.

This certainly makes a very strong showing in favor of the boiling test, at least considered from a laboratory standpoint.

In order to obtain some idea of the relative strengths obtained from cements that passed and that failed in the test, Table III. was compiled from 200 nearly consecutive tests of a single brand, 100 of them failing in the test and 100 passing.

TABLE III.—COMPARISON OF THE TENSILE STRENGTH OF BRIQUETTES PASSING AND FAILING IN THE BOILING TEST.

Age.	Failing in test.		Passing test.	
	Neat.	1 : 3 sand.	Neat.	1 : 3 sand.
1 day	530	....	391	
7 days	817	197	643	237
28 days	749	273	727	303
2 months	713	274	732	312
3 months	702	242	749	314

It will be noticed that the early strength of the neat tests of those samples failing to pass the test is much the greater, while

the opposite is true of the sand samples. This table, while covering but a comparatively small number of tests, may, however, be considered fairly typical of the relations of the strength and the boiling tests, although, of course, exceptions may quite often be found.

In order to show the great value sometimes obtained from the results of the boiling test, several examples are given in Table IV. of tests of cements occurring in the regular routine work of the laboratory.

The first example is particularly remarkable in that at twenty-eight days there was absolutely no sign of failure whatsoever except in the boiling test.

All of these samples were normal in specific gravity, fineness, and time of setting, and both the tensile strength and the normal pats passed a good test at seven days, the boiling test giving the only indication of an unquestionable failure occurring at a later period. It should also be stated that these are not exceptional or "freak" cases, but examples of a common, although not frequent, occurrence.

Another point of considerable interest regarding the boiling test is this: The statement is frequently made that although a cement failing in this test may be otherwise sound, a cement passing the test may always be considered entirely safe; although this is generally true, it is by no means an invariable rule. It may often happen that a cement may pass the boiling test well, and yet check and disintegrate in the normal tests, particularly if the cement be slow setting, high in lime, and the test made soon after the specimen is molded. In these cases it seems that the boiling at first tends to hydrate the lime and render it inert, although it would be active under normal conditions. It is possible that sulphate of lime may act in this way in holding back the true setting of the cement, but giving it an artificial hardness due to its own hydration, thus giving it sufficient coherence to hold together in the test, but allowing the boiling water to act on the lime before it has hardened, thus enabling it to hydrate without injury. It is thus frequently possible to add small quantities of lime to a sound cement and treat it in such a way that it will pass the boiling test perfectly and yet fail under normal conditions. The writer has recently seen the photograph of a test made in which as much as

TABLE IV.—EVIDENCES OF FAILURE IN CEMENT INDICATED BY THE BOILING TEST.

Tensile strength.							Normal pat tests.				
Neat.				1 : 3 sand.			Air.		Water.		Boiling test.
1 day.	7 days.	28 days.	4 months.	7 days.	28 days.	4 months.	28 days.	4 months.	28 days.	4 months.	
522	793	797	Disintegrated.	204	257	52	Very slightly curled; left glass.	Badly curled; soft and crumbly	Left glass.	Disintegrated.	Disintegrated.
503	872	586	Disintegrated.	184	239	47	Very slightly curled; left glass.	Badly curled; soft and crumbly.	Left glass.	Disintegrated.	Disintegrated.
498	762	700	Disintegrated.	176	231	119	Very slightly curled; left glass.	Badly curled; soft and crumbly.	"O. K."	Disintegrated.	Disintegrated.
427	751	603	223	183	227	94	Very slightly curled; left glass.	Disintegrated.	"O. K."	Disintegrated.	Disintegrated.
503	827	717	177	220	252	132	Left glass.	Badly curled; soft and crumbly.	"O. K."	Disintegrated.	Disintegrated.
492	883	620	202	195	217	147	Left glass.	Badly curled; soft and crumbly.	"O. K."	Disintegrated.	Badly checked
535	864	743	94	197	241	77	Very slightly curled; left glass.	Badly curled; soft and crumbly.	"O. K."	Badly curled and checked.	Checked and cracked.
502	829	722	320	203	247	65	Very slightly curled; left glass.	Badly curled; soft and crumbly.	"O. K."	Badly curled and checked.	Checked and cracked.
Neat tests not made.				172	219	93	Very slightly curled; left glass.	Badly curled; soft and crumbly.	"O. K."	Badly curled and checked.	Checked.
Neat tests not made.				198	231	101	Left glass.	Badly curled; soft and crumbly.	"O. K."	Badly curled and checked.	Checked.

NOTE.—All of these cements were normal in specific gravity, time of setting, and fineness.

15 per cent. of lime was added to a cement, and boiled, with excellent results, although the normal pats failed in a very short time.

Now, finally, we come to what is after all the most vital question of all, and that is the relation of the results of the boiling test to the conditions found in actual work, and there every tester of cement runs against a stumbling block, for while almost everyone connected with testing can cite instances of failures in boiling being corroborated by failure in the work, it nevertheless cannot be denied that in the vast majority of cases work done with cement determined in the laboratory to be unsound will give most excellent results in practice and show not the remotest sign of any sort of failure.

This condition of affairs is due to two reasons, one of which can be readily explained, while the other is not so simple.

The reason that most cement shows such a radical difference in the results of the laboratory and of actual use is the fact that almost invariably the test is made considerably before the cement is used, a week almost always elapsing and often as much as a month, thus giving it plenty of time to season, and render the expansive elements ineffective. The shortest time customarily allowed, that of one week, being very often sufficient to make the difference between a radically unsound cement and one which is normal.

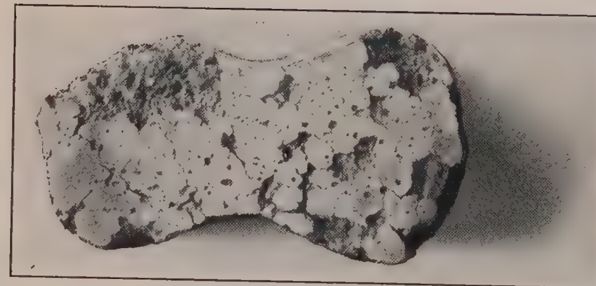
The second reason is that the disintegrating action of a cement is always far greater when mixed neat than when mixed with an aggregate, and the greater the amount of the aggregate the less the tendency to unsoundness. This can often be observed in the laboratory tests, cements often completely disintegrating in the neat briquettes, but retaining their strength in the sand tests.

Table V. shows a few instances of this sort.

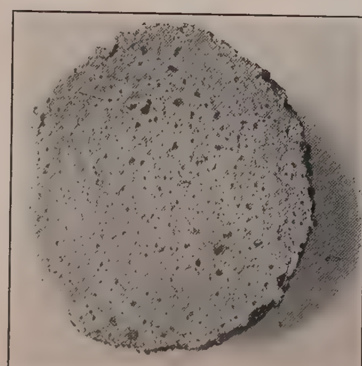
TABLE V.—EXAMPLES OF FALLING OFF IN THE STRENGTH OF NEAT BRIQUETTES WITHOUT SIMILAR ACTION SHOWN IN SAND BRIQUETTES.

Neat.					1 : 3 sand.			
1 day.	7 days.	28 days.	4 mos.	1 year.	7 days.	28 days.	4 mos.	1 year.
450	782	705	392	203	180	252	309	314
493	717	801	317	241	172	247	283	297
429	685	793	598	318	209	251	298	323
473	791	790	502	291	192	267	287	301
502	823	752	421	200	184	229	252	251
423	802	741	511	277	212	237	290	308
479	784	782	520	321	202	238	301	318
461	791	797	493	290	178	251	277	276

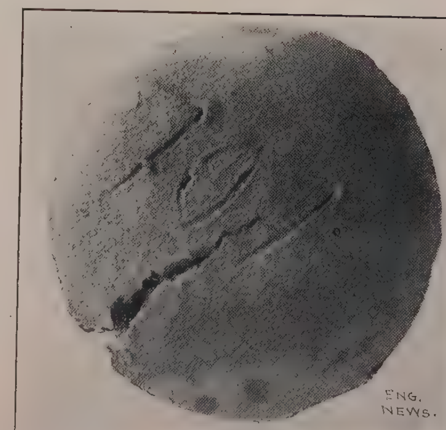
PLATE IX.
PROC. AM. SOC. TEST. MATS.
VOLUME III.
TAYLOR ON SOUNDNESS TESTS OF PORTLAND CEMENT.



Briquette kept in water.



Normal air pat.



Normal water pat.

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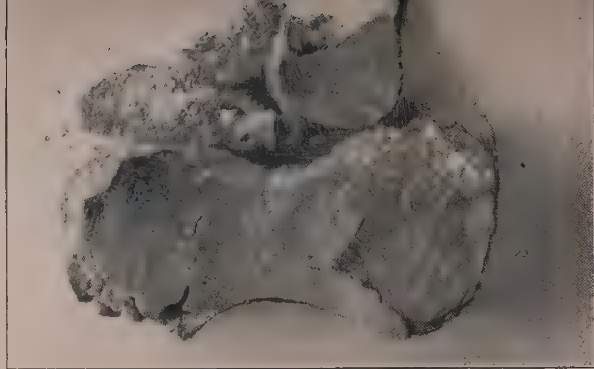
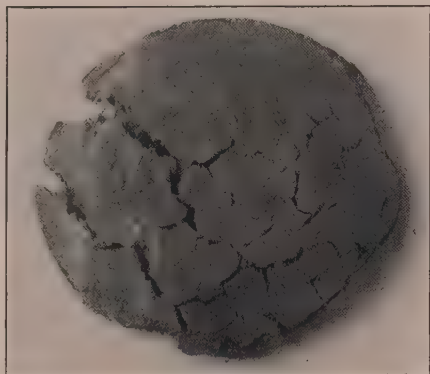


Briquette kept in water.



Normal water pat.

Normal air pat.

SAMPLE No. 2.

Failed in boiling test, but sound in every other test up to twenty-eight days. Photographed at four months.

FIG. 3.—EXAMPLES OF UNSOUNDNESS DEVELOPED BY BOILING TEST. (Table IV.)

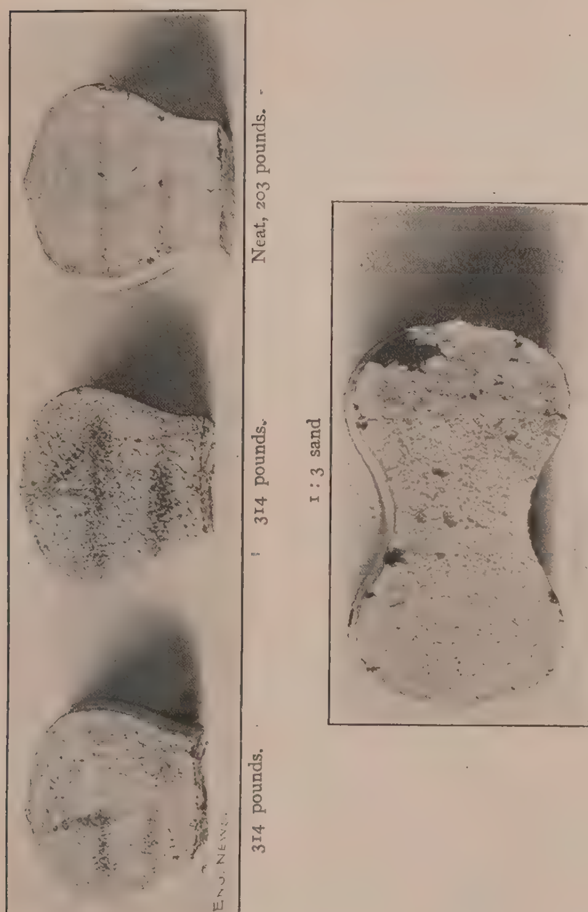


FIG. 4.—Neat briquettes cracking and disintegrating, while sand briquettes of same cement remain sound. (Table V.) Photographed when one year old.

In conclusion, it can be stated that although in the great majority of cases the results of the boiling tests can be considered as being indicative of the future behavior of the cement from a laboratory standpoint, one cannot be too careful in condemning cements on this test alone unless his experience has covered a large

number of tests and many varieties of material, and even then it is questionable if the rejection of cements on the results of this test alone is justifiable. It is often policy to hold a cement for a week or two, so that it may have an additional amount of seasoning; but to reject a cement outright will usually only result in much annoyance to both engineer and contractor without anything being gained.

It is much to be regretted that, in spite of the great importance and extended use of the accelerated tests of cement, so little work of value has been done on their investigation, and it is believed that this Society could do nothing of greater importance to the cement trade than to inaugurate a systematized investigation of the subject, in the hope of clearing up some of the many unexplained phenomena connected with it, and of devising some form of this test in which the results are not open to so much question.

DISCUSSION.

CLIFFORD RICHARDSON.—In my opinion, Mr. Taylor's tests on the soundness of Portland cement are by far the most valuable that have yet been conducted and throw much light on the subject. While confirming the results of German investigators, Mr. Taylor has carried his experiments much farther. The facts accumulated will be of great value to the Committee on Uniform Testing of Portland Cement, and in preparing uniform specifications. Mr. Richardson.

W. K. HATT.—The results related by Mr. Taylor confirm the speaker in his opinion, which is based on results of experience, that the boiling test, while not a perfect and always reliable instrument, is yet very useful for the city engineer of the small cities, who has to decide the acceptance of small lots of a variety of brands of cement. These city engineers of small cities receive considerable defective cements, some of which, no doubt, have been rejected from use in larger jobs. Mr. Hatt.

E. S. LARNED (by letter).—In testing cement for acceptance, it is the common practice to sample the shipments as soon as received on the work, and depending upon the requirements of the engineer, the cement may be held until the results of the 24-hour, 7-day, or 28-day period have been determined. Mr. Larned.

The number of samples taken vary from one in five to one in twenty barrels, and it is a common practice to consider the average of the results obtained. I know of no rule governing the determination of averages, but in my experience have found occasions where results of the operator are at such variance that extremes are frequently excluded in determining the mean. I believe these extremes are almost entirely due to the difference in manipulation of the samples rather than any difference in the quality of the cement. It frequently happens that one or two briquettes for a given period will break so much below the requirements that the quality of the cement might well be questioned, and yet, where the average is satisfactory, sometimes even including the extremes,

Mr. Larned. we seldom find any attempt made to exclude the barrel or barrels from which the poor results were obtained. Moreover, it is readily seen that this would be quite impracticable, so that the question naturally arises, Should we take the mean of the results of a number of individual samples, or should all the samples be thoroughly mixed before testing, and the mixture be regarded as representative of the shipment considered?

I believe there are many good reasons to support the latter view, and also the view of the Army Commission, recently appointed to fix the requirements for Portland and natural cements, wherein the mean of results is not taken, but only the best results in each series, the inferior results being ascribed to the personal equation of the operator.

In connection with the tests for soundness which have been so ably considered by Mr. Taylor, I desire to emphasize the fact that the cement is not only given an opportunity of seasoning between the time of its arrival and its actual use, which may be from one week to twenty-eight days or longer, whereas the tests are made at once; but in the actual operations of the work, where the cement is unbarrelled and mixed with sand, more or less damp, it receives pretty thorough aeration, with some beneficial hydration in this operation. It is obvious, therefore, that laboratory determinations do not fairly represent the action of the cement in its actual use, and that engineers are coming to recognize this, I believe it to be shown in some of the more recent specifications, wherein it is stated that the boiling test, if unfavorable, may not be regarded as sufficient cause for rejection, and that chemical analyses will be made, and perhaps the boiling test repeated at a later period.

Mr. Lesley. R. W. LESLEY (by letter).—Mr. Taylor's paper suggests reference to the investigations of the Society of German Portland Cement Manufacturers in the matter of accelerated tests. These tests were carried on in connection with the Royal Testing Laboratory, at Charlottenburg.

The subject was opened up some twelve years ago by the Society of German Portland Cement Manufacturers, and a reference to all the numbers of their *Proceedings* since 1891 shows experiments and reports on these accelerated tests and a constant

adherence to the standard pat test of the Society. In February, 1894, the matter was brought up in a lengthy discussion by Tetmajer, Bauschinger, Michaelis, and Prussing, and a committee of the Society of German Portland Cement Manufacturers, in connection with the Royal Mechanical Testing Laboratory, at Charlottenburg, undertook the investigation. Contemporaneous with this discussion before the German Society, there was a voluminous discussion published in the *Transactions of the American Society of Civil Engineers*, October, 1892, growing out of the presentation by Captain W. W. Maclay of these same accelerated tests. Mr. Lesley.

The German experiments in question were made with ten cements of different character, which were subjected to accelerated tests and were made into medallions and pieces of cement ware, and were also used in work. The final conclusions of the committee as reported in the *Proceedings* of the German Society for the year 1900 are as follows:

"*Final Conclusions.* The result of the investigation may therefore be summed up as determining that none of the so-called accelerated tests for constancy of volume is adapted to furnish a reliable and quick judgment in all cases concerning the practical applicability of a cement. The investigation has further proved that all ten cements, which withstood the pat test in the normal system of testing, are practically constant in volume when used in test pieces and cement wares. The increase in strength of the test pieces with water and air hardening speaks well for the practical utility of the cements.

"The assertion quoted early in the report that the normal or standard tests were insufficient, particularly when the cement is to be hardened in the air in its practical application, has received no confirmation by the investigation of the commission. Nevertheless, the commission is ready to carry out still further investigations and requests the sponsors for the accelerated tests for soundness to provide sufficient quantities of such cements as pass the normal tests do not satisfy the accelerated tests and prove unsound in practical service. The cement should be sent to the Royal Testing Laboratory until October 1, 1900. Until it has been possible to discover a test for soundness which is reliable and can be carried out in a shorter time than the standard test, the pat test of the normal specifications must be retained as decisive. In the practical use of Portland cement, it is nevertheless to be recommended for such exceptional cases as require the cement to be subjected to high temperatures, that the tests be conducted under similar conditions of high temperature as the above-mentioned accelerated tests."

Two years later, these tests having been carried out for a still longer period, the Society of German Portland Cement Manufacturers reported as follows:

"After having made tests for the length of two years, the Commission for

Mr. Lesley. Deciding as to the Constancy of Volume and Adhesive Power of Portland Cement came to the conclusion that none of the so-called accelerated tests, boiling tests etc., was capable of affording in all cases a quick and reliable judgment in regard to the practical usefulness of a cement. Last year those tests have been ended after four years, and Mr. Gary, head of the Department of the Royal Testing Laboratory at Charlottenburg, has published those results made by his Department and also by the above-mentioned Commission in the communications from the Royal Testing Laboratory, the main contents of which are as follows:

"Even the 4-year tests have confirmed the results and conclusions of the 2-year tests. Neither the 4-year observations nor measuring the expansion, nor the firmness of the ten cakes tested, which were considered not up to the standard, justifies us in declaring those cements useless for practical purposes."

After some discussion on this report, which sustained the German normal test, which is as follows:

(Pats of neat cement are made, which stand 24 hours in damp air, and are then placed some in water and some in air, and observed until 28 days old. If they do not become distorted or cracked during this time, the cement is considered sound.)

a resolution was adopted by the Society accepting the report of the committee to the effect that it considered its work ended. The committee was thereupon discharged, and the German normal test was left unchanged.

The most important thing shown by Mr. Taylor is that boiling means seasoning, and his figures on the cements boiled after holding them for a period, as shown in Table I., prove conclusively this fact and throw us back to the old practice which was used by the English engineers many years ago, and is referred to in an interesting paper on the "Vernwy Dam," read before the British Institute for Civil Engineers.

These figures of Mr. Taylor are corroborated by experiments at our own works in our own laboratory, and also by the testing experts of the New York Rapid Transit Commission, who are testing our cement at our works. They demonstrate very clearly that, as a matter of practice, the right time to make the accelerated tests of a cement is not at the *beginning* of the testing operation when the briquettes are made, but at the *conclusion* when the briquettes are broken. In other words, if the practice in the testing of cement on public works is only to accept cement after 28-days' test, and not to allow it to be used until after that

test is passed, it certainly appears clear that the time to make the accelerated tests, which takes at the most 24 hours to make, is when the final test briquettes are broken and not at the beginning of the testing operation. Mr. Lesley.

The cement which is to stand the accelerated test is the cement which is to be delivered on the work and is ready for delivery, not the cement which is hot from the mill-stones or is just made and is submitted immediately after manufacture to the testing laboratory.

It can be readily understood that for the purposes of the making of 7-day and 28-day tests and for the purpose of having tests of fineness and specific gravity, the manufacturer submits the cement promptly after manufacture, and the consumer receives it in the condition for the ordinary mechanical testing purposes. Then the cement which is received is tested for tensile strength and the other requirements, and, having passed these requirements, and being in a condition to be delivered on the work, so far as the tensile strength and other physical tests are concerned, at the expiration of either the 7-day or 28-day periods, it then becomes the time to determine its condition, so far as expansion and contraction is concerned, as then is the time it is to be actually used. This, therefore, is the period at which these tests should be made for constancy of volume.

In view of the great doubt that seems to exist in the minds of nearly all engineers as indicated by Mr. Taylor's paper, and as indicated in the reports of the Board of Engineers, U. S. A., Professional Papers No. 28, and as pointed out in the report of the American Society of Civil Engineers, January 21, 1903, as to the absolute reliability and efficacy of boiling, hot-water, and other accelerated tests, it would seem that this method of making the accelerated tests at the expiration of the tensile and other tests at the time of the delivery of the cement on the work would be the proper way, and would overcome many of the objections now urged against this test, which, to my mind, is at the most a doubtful and uncertain expedient.

The Board of Engineer Officers' (U. S. A.) report says, under the head of "Accelerated Tests:" "This test is proposed as suggestive or discriminative only. Except for works of unusual im-

Mr. Lesley. portance, it is not recommended that a cement passing the other tests proposed shall be rejected on the boiling test."

The report of the American Society of Civil Engineers' Committee says, under the head of "Constancy of Volume:" "In the present state of our knowledge it cannot be said that cement should necessarily be condemned simply for failure to pass the accelerated tests; nor can a cement be considered entirely satisfactory simply because it has passed these tests."

Certainly, if experience shows that this test really is a measure only of the seasoning of the cement, it would be better to make it at the end of the testing period, because at that time the cement will have aged and will more resemble the condition in which it is to be used, and the boiling test will give a better indication of its true value. The whole question of the soundness test is one that is particularly worthy of consideration and investigation, from the fact that we are in this country the pioneers in the use of rotary kilns, and the general literature hitherto upon this subject of accelerated tests has been literature based upon the product of the dome kilns used in Europe, and it is just such work that Mr. Taylor is doing that will enable us to determine whether the accelerated tests applicable to dome kiln products are safe to be used with rotary kiln products, or whether they will have to be modified in order to be a true criterion for the product of the rotary kiln

TESTS OF PORTLAND CEMENT MORTAR EXPOSED TO COLD.

By C. S. Gowen.

The following experiments were made with a view to getting some definite information on the effect of frost on Portland cement mortar, under the different conditions in which it may be desired to use it in cold weather. No facilities existed for maintaining a prolonged cold or uniform temperature, and the briquettes were accordingly exposed to the open air, and so kept until it was evident that the tendency to "dry out" unduly was reducing their proper strength and creating a condition by which no basis of comparison with ordinary results could be had.

The briquettes were accordingly placed in water in July at the end of the first 6 months of the tests, and the author is inclined to the opinion that if this had been done earlier, at the end of the 3 months' tests, the 12 months' results would have showed much nearer the average 12 months' results of tests made in the ordinary way of briquettes kept in water continuously until broken. In the table given below each breaking weight given is the mean of 8 briquettes broken, and it may be said that each set of breakings showed marked uniformity in the strength of the briquettes.

The results are from experiments made by the author while acting as Resident Engineer for the Aqueduct Commissioners of the city of New York, in charge of the New Croton Dam, and to them the author wishes to make proper acknowledgment for the use of these data.

Effect of Cold upon Setting.

In the case of this lot of cement, which was moderately quick setting (taking heavy wire in 63 mins. 2 to 1 briquettes and taking heavy wire in 71 mins. neat briquettes, under normal conditions of testing in laboratory), moderate cold, 22° and upward, delays setting, but does not freeze. This is shown by the set of tests made for the intended temperature 24° to 32° of exposure.

The second set of tests (intended temperature of exposure 24° to 10°) show in the case of the 28th day and 3 months' breakings (temperature 24° and 22°, respectively) a delayed setting which resulted in freezing during the night. The other breakings 6, 9 and 12 months, show, at lower temperatures, quick freezing.

The third set of tests (intended temperature of exposure 24° to 32°) were exposed to moderate cold after having taken heavy wire in laboratory.

The fourth set, a mixture with brine (intended temperature of exposure 20° to 10°), shows clearly the influence of the cold in delaying the set, as well as the effect of the brine in delaying freezing.

At temperature of exposure 16° +, the set occurred in 6 hours; 16° —, no set in 4 hours and no sign of freezing; 14° +, no set in $2\frac{3}{4}$ hours and no sign of freezing; 20° +, a set in $5\frac{1}{2}$ hours with some indications of freezing; 26° —, no set in $2\frac{1}{2}$ hours and no sign of freezing.

The fifth set of briquettes was exposed at a steady temperature of 18° ±, and all froze in 35 mins.

CONCLUSION.—A moderately quick setting cement can be used in temperatures about 20° without freezing with a 2:1 mixture.

The use of brine delays freezing, at least, at temperatures of about 15°, if it does not wholly prevent it before the set has occurred.

EFFECT OF COLD UPON BREAKING STRENGTH.

It is apparent that the general falling off at the end of six months is due to air exposure, the rise for 9 and 12 months after being placed in water being marked, and the author is of the opinion that had briquettes enough been made for 15 and 18 months' breakings there would have been a uniform increase in strength, comparing favorably with general results from laboratory tests; a summary of which has been added to the tabular statements. The 6 months' breakings of the various sets show a much greater uniformity than those of 1 month and 3 months, as might have been expected, the extremes being 287 and 366 pounds.

At 9 months sets 1 and 4 agree closely.
sets 3 and 5 agree closely.

While set 2 is lower in its breaking weight than either of the others.

At 12 months sets 2 and 4 agree closely.
sets 3 and 5 agree closely.

While set 1 comes between these extremes, which vary between 510 and 602 pounds, an extreme variation, not much greater than indicated by the 6 months' breakings, and much less than that shown by the 9 months' results.

CONCLUSION.—The general result is favorable to the use of brine at low temperatures; also there is no indication that freezing reduces the ultimate strength of the mortar, although it delays the action of setting.

In this particular example the frozen set No. 2 shows better at 12 months than frozen set No. 5, but not so well at 9 months, where the relative difference is the other way.

At 12 months sets Nos. 2 and 4 ("frozen at low temperature" and "brine") agree closely.

Set No. 1 comes next ("mixed at moderate temperature"), and sets Nos. 3 and 5 follow.

There seems to be nothing in the results shown in set No. 3 to indicate an advantage in securing a set before exposure to freezing temperature.

The above results are relative rather than conclusive, as it is impossible to say what would have been the results at the end of the year, and how they would have compared with the general average given for briquettes tested under normal conditions if they had not been exposed to the varying temperatures of spring and early summer and to "drying out."

These briquettes were mixed in February, 1897, as opportunity and the required temperatures occurred, and the records of the time of setting were made as carefully as was practicable under the circumstances.

The temperatures of the air at the time of the final test for the set were not taken, but, as a rule, the temperature rose or fell, as indicated, steadily during the time that elapsed while the observation was made. These results are submitted for what they may be worth, as the author does not know of any series of tests extending over so long a time, and at the same time covering such extremes and variations of temperature.

The following, showing the results obtained by tests made under ordinary laboratory conditions, when brine was used, are added here, and the conclusion seems to be plain that the effect of brine is to delay setting temporarily, while not affecting the ultimate strength of the mortar materially.

Giant Portland, 2 to 1 briquettes.

Per cent. of water used to weight of cement, 40.

Time to take heavy wire, fresh-water briquettes, 241 mins.; salt-water briquettes, 306 mins.

	1 week.	1 mo.	3 mos.	6 mos.	9 mos.	12 mos.
Fresh water used . . .	236	289	414	549	554	572
Salt water used . . .	126	231	294	424	452	576

Giant Portland, 3 to 1 briquettes.

Per cent. of water used to weight of cement, 50.

Time to take heavy wire, fresh-water briquettes, 350 mins.; salt-water briquettes, 407 mins.

	1 week.	1 mo.	3 mos.	6 mos.	9 mos.	12 mos.
Fresh water used . . .	112	183	268	335	351	458
Salt water used . . .	68	131	215	266	301	413

Standard sand used (crushed quartz).

The brine used was strong enough to float a potato, about a 10 per cent. solution by weight.

Each of the above results is the mean of ten breakings in pounds per square inch.

The briquettes were placed in air 24 hours, and then immersed in water until broken.

BREAKING WEIGHTS OF 2 : 1 MORTAR BRIQUETTES, POUNDS PER SQUARE INCH, EXPOSED TO COLD, AT NEW CROTON DAM.

Cement used Giant Portland, sand used crushed quartz, Lot 209, 1476 barrels. Each breaking weight given is the mean of eight breakings.

Temperature intended.	28 days.		
	Breaking weight, pounds per square inch.	Temperature exposure, degrees.	Time to take heavy wire.
24 to 32°	370	22 r.	4 hours.†
24 " 10	458*	24 f.	Night.
24 " 32	371	28 f.	65 minutes.
20 " 10	272	16 r.	6 hours.
20 " 10	255	18 s.	35 minutes.

Temperature intended.	3 months.		
	Breaking weight, pounds per square inch.	Temperature exposure, degrees.	Time to take heavy wire.
24 to 32°	474	27 r.	4½ hours.†
24 " 10	455	22 s.	Night.
24 " 32	413	28 f.	65 minutes.
20 " 10	360	16 f.	4 hours r.‖
20 " 10	246	18 s.	35 minutes.‡

6 months.

Temperature intended.	Breaking weight, pounds per square inch.	Temperature exposure, degrees.	Time to take heavy wire.
24 to 32°	366	34 f.	
24 " 10	347	12 r.	15 minutes.‡
24 " 32	314	28 f.	65 minutes.
20 " 10	287	14 r.	2¾ hours r.+∥
20 " 10	300	18 s.	35 minutes.‡

9 months.

Temperature intended.	Breaking weight, pounds per square inch.	Temperature exposure, degrees.	Time to take heavy wire.
24 to 32°	553	28 r.	4½ hours.†
24 " 10	381	14 r.	15 minutes.‡
24 " 32	452	28 f.	65 minutes.
20 " 10	567	20 r.	5½ hours.×
20 " 10	437	18 s.	35 minutes.‡

12 months.

Temperature intended.	Breaking weight, pounds per square inch.	Temperature exposure, degrees.	Time to take heavy wire.
24 to 32°	553	26 r.	7 hours s.
24 " 10	586	16 r.	45 minutes.§
24 " 32	510	28 f.	45 minutes.
20 " 10	602	26 f.	2¼ hours.‡ ∥
20 " 10	512	16 s.	35 minutes.‡

REMARKS. 24 to 32°: Placed in cold air at temperature noted immediately after mixing: fresh water used. 24 to 10°: Placed in cold air at temperature noted immediately after mixing; fresh water used. 24 to 32°: Took heavy wire before being placed in cold air; fresh water used. 20 to 10°: Placed in cold air at temperature noted immediately after mixing; brine used. 20 to 10°: Placed in cold air at temperature noted immediately after mixing; fresh water used. In column of "temperature of exposure" r. indicates a rising temperature; f. a falling temperature; s. a steady temperature. All briquettes were left in open air in a dry but not sunny place until the three months' break was made (about April 15); then they were put in a damp place until the six months' break was made (about July 15); and then they were placed in water until finally broken. The brine used was a solution strong enough to float a potato, about 10 per cent. by weight of salt to weight of water.

* This set was broken on a day when the temperature was 16°; a ninth briquette was thoroughly thawed on same day and broke at 210 pounds.

† Did not appear frozen when it took heavy wire.

∥ Had not set at end of time noted.

‡ Frozen at end of time noted, and took wire.

× Some signs shown of freezing.

§ Froze slowly and took heavy wire.

+ One briquette made with fresh water froze and took heavy wire in twenty minutes.

AVERAGE BREAKING WEIGHTS OF 2 : 1 MORTAR BRIQUETTES, GIANT PORTLAND CEMENT, BROKEN AT NEW CROTON DAM IN 1896, 1897, 1898.

		Lot 209, 1476 bbls.
Time	28 days.	28 days.
Number of breakings	690	10
Average breaking weight, pounds per square inch	441	483
Time	3 mos.	......*
Number of breakings	215	......
Average breaking weight, pounds per square inch	563	......
Time	6 mos.	......
Number of breakings	185	......
Average breaking weight, pounds per square inch	657	......
Time	9 mos.	......
Number of breakings	155	......
Average breaking weight, pounds per square inch	671	......
Time	12 mos.	......
Number of breakings	165	......
Average breaking weight, pounds per square inch	663	......

Time of taking heavy wire, mean of 70 tests (2-1), briquettes, 63 minutes ; mean of 70 tests, neat briquettes, 71 minutes ; average breaking weight, mean of 70 tests (2-1), briquettes, 1 week, 344 pounds.

* Normal test of this lot not continued after twenty-eight days.

DISCUSSION.

W. P. Taylor.—A rather extensive series of tests on the effect of freezing on cement mortars was recently made in the Philadelphia Laboratory, and the well-recognized fact was clearly brought out that mortars made in freezing weather and subsequently allowed to thaw without a second freezing were but little injured by this process, but that mortars subjected to several alternate freezings and thawings were readily broken up and disintegrated, this latter effect being probably due more to a mechanical than a chemical action. It was also shown that the addition of salt was very beneficial to cement mortars subjected to alternate freezings and thawings, although, even in the most favorable instances, the strength of these mortars never equalled those made at normal temperatures. Another fact brought out was that the addition of salt up to solutions of 20 per cent. had no appreciable effect on the strength or soundness of cement under normal conditions. Mr. Taylor.

The results of these tests would seem to indicate that it is always inadvisable to lay cement in freezing weather, but that if such work is necessary, every precaution should be taken to keep the material warm, so that initial set at least can take place before freezing, and also that under such conditions the use of salt solutions is beneficial.

R. W. Lesley.—Experiments at the works of the American Cement Company and also experiments conducted by the late Colonel William M. Patton at the time of the construction of the Baltimore and Ohio Railroad bridge over the Schuylkill River at Philadelphia, seem to indicate that upon the mixing of cement with water a chemical action is set up, which results first in mortar and then in the formation of the stone. When, during this chemical action, the water necessary for carrying it on changes into crystals by freezing, the chemical action is arrested and the setting goes on no longer, and if mortar of this kind, hard-frozen, is allowed to remain in cold weather and subsequent thaws, the water Mr. Lesley.

Mr. Lesley. goes back to the cement, the crystals having been dissolved, and the setting goes on. This is, however, what might technically be called a "second setting."

Experience shows that mortars thus treated lose very little if any of their ultimate strength. The loss of strength in frozen mortars occurs where a slight set has begun and is arrested by freezing and subsequently is started by thawing. Action of this kind, which means a repeated number of chemical actions causing a slight set, only to be suspended when the uncombined water is again frozen, would ultimately end in the destruction of the mortar, just as the retempering of a mortar eight or ten times would destroy its setting qualities.

SOME OBSERVATIONS ON THE EFFECT OF WATER AND COMBINATIONS OF SAND UPON THE SETTING PROPERTIES AND TENSILE STRENGTH OF PORTLAND AND NATURAL CEMENTS.

By E. S. Larned.

In the use of hydraulic cement it has become quite possible, through the careful observations and experiments of the engineer and chemist, to compass and provide for the variable natural conditions under which the cement must be used, and when it is carefully selected and treated intelligently in the practical work of construction, enduring monuments are founded, to the honor and credit, not alone of the designer and builder, but to the pioneers and courageous supporters of this important industry in the country, who have persevered in face of many discouraging and adverse conditions until the American product is recognized as the equal, if not the superior, of the imported.

While the rapid growth of the Portland cement industry since 1895, and the extended use of the material in all forms of construction, may well be taken as a tribute to its improvement and reliability, the better understanding and appreciation of engineers and architects must also be considered of the utmost importance. Hydraulic cements have been made and used for more than a century, and yet it has remained for investigators of comparatively recent years to throw much light upon the subject. One of the most important objects yet to be attained is the standardization of tests and specifications, and it would seem that this could best be accomplished through the agency of your Society, and the representative engineering societies. Of equal and even greater importance is the proper interpretation of the results of tests prescribed, and it is here that the principal educational work must be done.

There is to-day, among users of cement, much conflict of opinion upon some of the most vital principles governing the acceptance of this material, and the natural outcome of this difference is, that some tests are specified that result in no advan-

tage to the user or the work in hand; others that give results that are misleading and fallacious as an indication of quality, interpreted as they are, and only serve to vex and hamper the manufacturer. In the absence of better information, it may be natural for the user of cement to entertain with suspicion the statements of the manufacturer affecting the quality of a cement in question, but it seems obvious that with standard specifications and uniform methods of testing, combined with full and up-to-date information upon the results of the several determinations made, there would follow greater uniformity in the material, less opportunity for dispute and a greater degree of confidence and mutual respect between men who are seeking the same attainments—excellence of material, design and workmanship, in all projects that mark the prosperity and progress of our country.

With an experience, covering nearly eighteen years, upon important hydraulic construction, I have found opportunity to observe many variable conditions affecting the requirements and use of cement, and I know of no material entering into construction of which so much is expected, that is subjected to the same or equal abuses, and when a failure is recorded, happily very few, how common it is to see the cause ascribed to the cement.

An idea will obtain in the classroom, office, or laboratory that, if carried out or closely approximated in the field, would give excellent results, but how often this is forgotten or overlooked, and crude, yes, cruel, methods of work be suffered, and this can, under present conditions, be said even of some work of cement-testing. Young men are sometimes selected for this work without previous experience or any knowledge whatever of the subject, and though one may have a high degree of intelligence, and be industrious and conscientious in his work, under good or indifferent supervision, yet the best that can be said of such a selection is that he is more likely to cause a good cement to be questioned than to pass a poor one, although the latter chance is not remote; meanwhile, little consideration is shown the manufacturer or the reputation of his product.

Once asked to explain the difference in results obtained by two testers working together, using the same amount of water in mixing and following the same method of moulding, etc., I

offered the somewhat parallel case of two cooks making bread from the same barrel of flour, same yeast, and same formula throughout, and yet the quality and appearance of the loaves would be quite unlike.

The personal equation, perhaps, may not be removed in testing cement, but other conditions that vitally affect the results can be brought to a more uniform basis, and these in ordinary practice may briefly be summed up as the quantity of water used to produce a paste or mortar of given consistency, time and manner of manipulation, method of molding, temperature of water and air, time and conditions of exposure in air and water, and rate of applying the load. The effect of water in retarding the induration of cements and reducing their tensile strength, particularly at short periods, has long been known, and more or less information has been published as the result of experiments made.

The writer was led to make a series of tests on these lines in somewhat more detail than anything he had seen published, and it is the result of this experiment that we will now consider. It may be stated that one man made the briquettes for the entire series, six for each period, at each interval in the amount of water used; the water in mixing was at a uniform temperature of 63° F., and the temperature of the air averaged slightly under 70° F., and fluctuated between 50° and 75° F. Two briquettes of A. S. C. E. Standard Form were gaged at a time, and beginning with the dry mixtures the molds were filled in three layers, each rammed successively until flushed, by hand, using a hardwood pestle, and finally struck off and smoothed with a trowel. The ramming process continued until the mixtures became too soft, when the molds were filled by pressing in with the thumb and trowelling. So far as possible, the briquettes were allowed to set in air, under a damp cloth, about two hours after taking the heavy wire, before immersion; this could not be followed uniformly, and some of the softer mixture were allowed to set in air overnight, and in a few instances the operator was obliged to wait late in the night to complete his observations. In determining the rate of setting, the Gilmore needles were used, and care was observed to use the same sample of cement throughout the series, and this was taken from the storehouse of contractors

engaged in the construction of large public work. The decimal scale of weights was used in gaging, the graduate glasses being carefully calibrated to agree, and the briquettes were broken on a Fairbanks machine of late pattern, the clips having roller bearings of composition metal.

Chemical analyses of the cements here considered were not made for this test, but the characteristics of the brands named are perhaps well known to many, and will be only briefly referred to. The Atlas and Giant brands of Portland cement both came from the Lehigh district of Pennsylvania, and, in their chemical composition, are in quite close agreement. The "Union," Natural, is also made from the crystalline cement rock of the Lehigh district, is light in color, and its composition is quite unlike the "Hoffman," which is dark in color, being made from the magnesian limestone of the Rosendale district, New York. "Union" more closely approaches the Portland Standard in composition and differs from the Hoffman noticeably in its lime and magnesia content, having about 50 per cent. lime and 2 per cent. magnesia, while the Hoffman has about 36 per cent. lime and from 16 to 18 per cent. magnesia, which is characteristic of about all the New York Rosendale cements. The low magnesia content, together with the very fine grinding of Union, cause it to be more active and quicker setting than Hoffman, and this is well shown in the table and diagram, particularly in the wetter mixtures.

As might be expected, this difference in the cements, tested neat, would be in greater contrast when combined with sand in concrete mixtures, and it was, in fact, the dissimilar results in practical work of construction that led to this experiment, and I regret that the experiment did not also include mortar mixtures, in the proportion of two sand to one cement, wherein conditions would obtain more closely approximating the operations of everyday practice.

From personal acquaintance with a recent large work of concrete construction the writer is forced to the conclusion that when any reliance must be placed upon the cohesive strength of Rosendale cement, within six months, and perhaps longer, depending upon the exposure and local conditions, great care must be exercised in proportioning the amount of water used, or, in the present

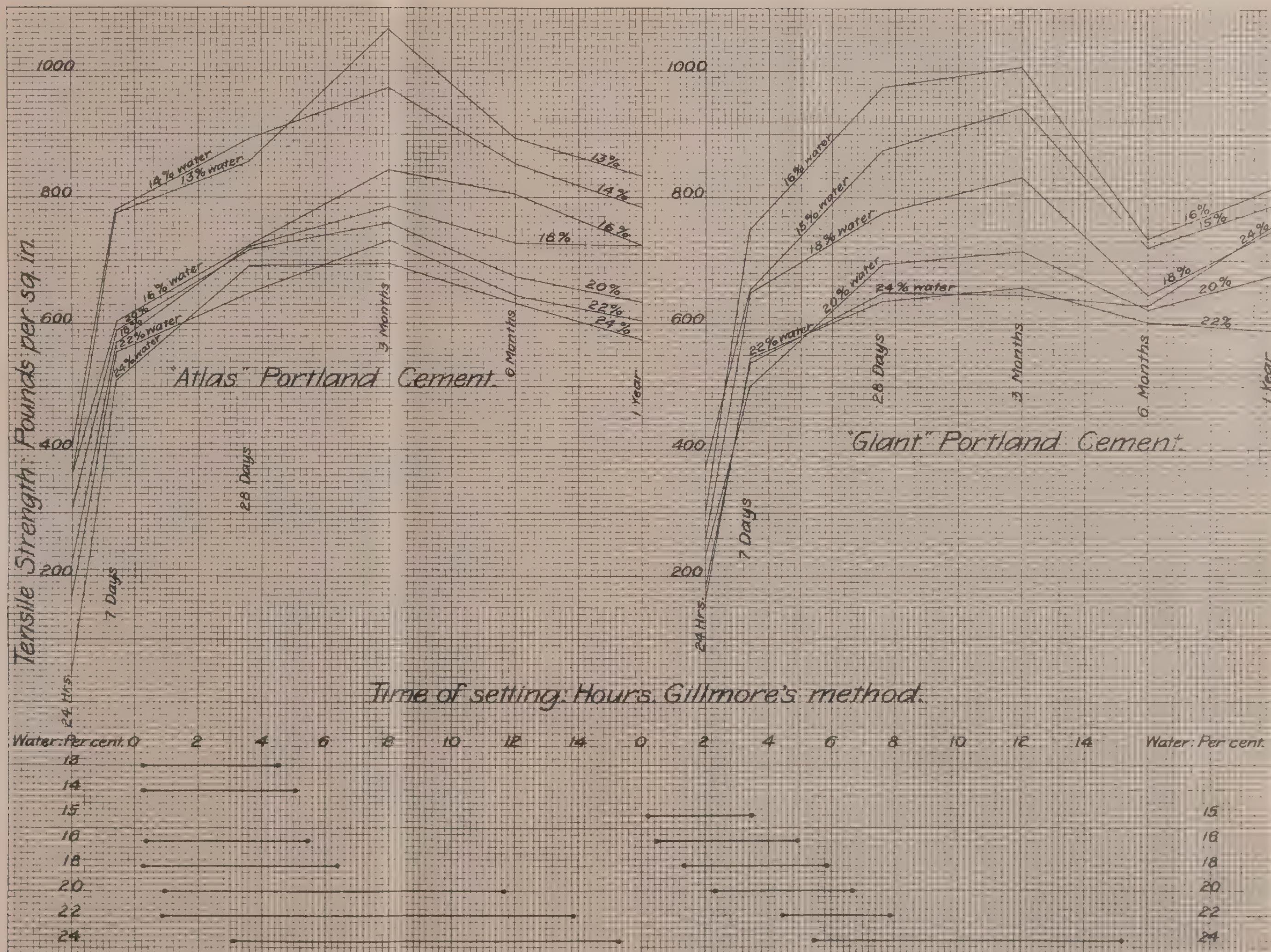


DIAGRAM SHOWING TENSILE STRENGTH AND RATE OF SETTING OF PORTLAND CEMENT.
MIXED NEAT WITH DIFFERENT PROPORTIONS OF WATER.

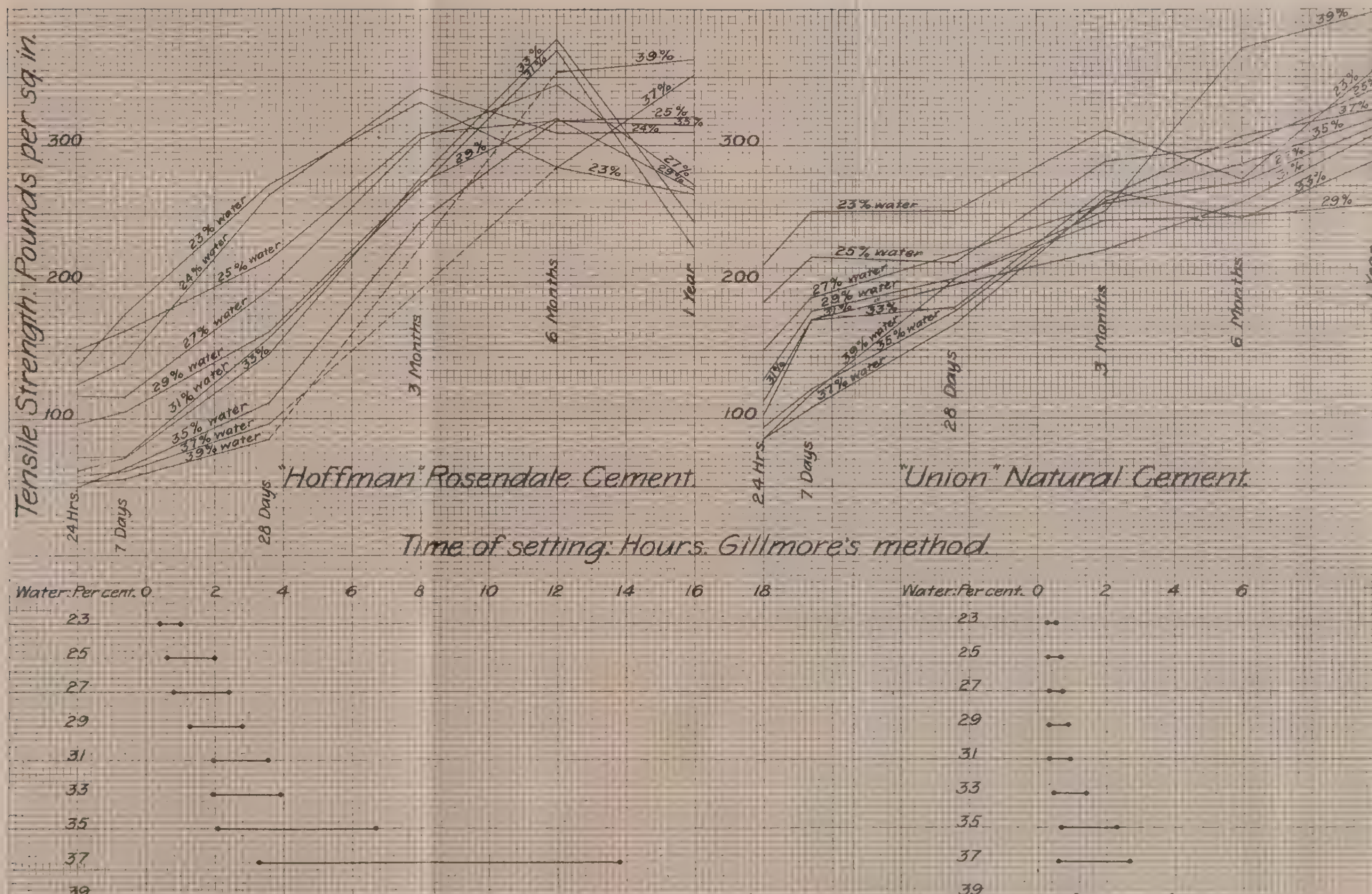


DIAGRAM SHOWING TENSILE STRENGTH AND RATE OF SETTING OF ROSENDALE CEMENT.
MIXED NEAT WITH DIFFERENT PROPORTIONS OF WATER.

day of wet concretes, in selecting a cement that successfully withstands the deteriorating influence of an excessive amount of water.

In the diagram of tensile results the dryer mixtures of the Hoffman cement show superiority up to the 28-day period, at which time it is quite marked and uniform; the gain in strength between the 24-hour and 7-day periods appears slow, and grows slower as the amount of water is increased; the improvement between the 7-day and the 28-day periods is better, but the rate of gain appears generally in favor of the dryer mixtures; the gain in all mixtures between this and the three months' period appears quite uniform, and develops a rapid gain for the wetter mixtures; after the latter period inconsistencies develop, and between six months and one year only the 37 per cent. and 39 per cent. series show any appreciable gain, and the wettest mixture appears superior at the end of the year, the others generally showing a falling off in strength, for which I can offer no explanation.

In the Union cement series the dry mixtures generally appear superior at the 24-hour and 7-day periods, the rate of gain is quicker and quite uniform; as in the Portland cements, the gain in strength of the wetter mixtures is more rapid between 7 days and 28 days, the wettest mixture having passed four of the series next below, and all of the series being closer together than at the two earlier periods; at three months only the 23 per cent. and 25 per cent. series held their superiority, the wetter mixtures rapidly overtaking all others and being in close agreement, with the exception of the 31 per cent. series, which made a slower gain; after this period peculiarities develop for which no explanation can be offered, but the uniform rate of improvement is noticeable in all instances, and the results at one year are better in each case than at any preceding period, the 23 per cent. and 33 per cent. series showing a falling off between three months and six months, with a good recovery at one year.

In the Portland cement series the rapid and uniform improvement between 24 hours and 7 days is noticeable, but the dryer mixtures generally hold their superiority; this is noticeably uniform in the Atlas cement at all periods; the maximum strength was attained at three months, after which, and up to one year, there

appears a steady falling off in strength, but from three months on the dryer mixtures are uniformly better.

The Giant cement also attained its maximum strength at three months, at which period the dryer mixtures also appear uniformly superior with the exception of the 15 per cent. series; and judging from the results of the series throughout the test, it would appear that there was not quite enough water used to perfect the crystallization of the cement. The Giant cement also shows a falling off between three months and six months, but a good recovery after this latter period in all but one series, 22 per cent., and the wettest mixture, 24 per cent., passed the three series next below at one year, two of them in fact at six months, and between six months and one year it showed a more rapid gain than any of the other series.

The personal equation is apparent in these tests, as in any test of the tensile strength of cements, but every effort was made to secure consistent and uniform results, and I will repeat that one man made the test throughout the entire series for the four cements named.

A tabulation is added showing the tensile strength of cement mortars in the proportion of one part of sand to one of cement, by weight, for Rosendale or Natural cements, and two parts sand to one cement for the Portland. A silicious sand was selected for this test, carefully screened to the sizes noted and combined in the proportions given in the table. The test was made to determine the relative value of sand grains of different diameters, in combination with cement, and also to study the effect upon the tensile results of adding fine material.

Few unwashed natural sands are free of dust, of a loamy or clayey nature, containing a high percentage of organic material, and in specifications usually calling for sand, clean and sharp and free from fine material, the importance of excluding this deleterious agent is recognized, but it is not always possible to enforce this absolutely, and from mechanical analysis of a large number of samples, and casual inspection of sand in use at various points, I am satisfied that much sand is used that contains 5 per cent. dust, and a good deal that carries as much as 10 per cent, and even more in some instances.

The fine material passing the No. 100 mesh screen, used in this test, was obtained from a clean white silicious sand, and if, with increasing amounts of this material, a falling off in tensile results appears, it can in no sense be taken as a measure of what would follow by using sand containing a dust of loamy or clayey nature, but is in a way suggestive. The cements used in this test were of the same sample as in the other tests previously referred to.

The sand mortar test is the true basis upon which to judge the value of a cement, and I believe the proportion of sand to cement should be the same as employed in the actual work of construction. Unfortunately this was not carried out in the above test of the natural cements, for the reason that results were desired, for purposes of comparison, with previous tests in the same laboratory, in which the crushed quartz or standard sand was used in the proportion of one part sand to one of cement.

Explanation of the results is hardly required; it will be noticed, particularly in the natural cements, how uniform and constant is the falling off in strength at the 7-day period, as the amount of fine material increased. This tendency, in the case of Union, disappearing at the 28-day period, at which time rather remarkable uniformity is found in all the combinations, except the 100 per cent. "Fine"; serious retardation in the improvement of the Hoffman, with the addition of fine material in the sand, is noticed between the 7-day and 28-day periods, the mixtures containing over 5 per cent. "Fine" remaining almost latent for this time, three of the combinations showing an actual loss, while four make a small gain, the average gain being two pounds; a rapid recovery is found, however, in these combinations between the 28-day and 6-month periods, and it is to be regretted that longer time tests were not made.

A tabulation of the results, excluding the series in which all "Fine" and crushed quartz were used, is herewith given:

	7 days.			28 days.			6 months.		
	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.
Hoffman	84	118	62	99	163	70	277	316	221
Union	139	156	108	198	222	183	336	362	302

The effect of the fine material upon the Portland cement is not so noticeable, even at the shortest period, except in the series with 100 per cent. and 50 per cent. "Fine," and no parallel can be drawn between the test with Portland cement and the results with Rosendale cement, using the same combinations of sand.

All of the above tests were made under the supervision of the writer while Division Engineer with the Metropolitan Water and Sewerage Board, Mr. F. P. Stearns, Chief Engineer, Boston, Mass., and I desire to make proper acknowledgment of the privilege of using this data.

TENSILE STRENGTH OF CEMENT MORTAR WITH SAND GRAINS OF DIFFERENT DIAMETERS.

Results given are the average of six briquettes.

Sand gauge per cent. used.				Natural cement mortar 1:1.								Portland mortar 2:1.			
				Water per cent.	"Union."			Water per cent.	"Hoffman."			Water per cent.	"Giant."		
No. 30.	No. 20.	No. 100.	Fine.		7 days.	28 days.	6 mos.		7 days.	28 days.	6 mos.		7 days.	28 days.	6 mos.
100	...	...	...	17	156	193	352	15	115	163	314	10½	286	288	412
...	100	...	...	17	151	194	349	15	118	146	286	10½	294	331	473
...	...	100	...	17	153	187	340	15	91	110	257	10½	201	226	294
...	...	...	100	17	100	123	307	15	71	76	186	10½	129	159	223
80	10	10	...	17	154	210	358	15	94	124	301	10½	361	380	486
70	15	12½	2½	17	142	190	332	15	86	107	254	10½	301	303	428
60	20	15	5	17	143	192	342	15	83	107	285	10½	307	311	419
50	25	17½	7½	17	140	208	345	15	80	89	291	10½	391	400	538
40	30	20	10	17	133	197	362	15	90	82	296	10½	350	355	475
30	25	30	15	17	123	191	329	15	78	77	266	10½	362	359	478
20	20	40	20	17	128	199	318	15	66	73	285	10½	317	374	480
10	15	50	25	17	122	201	324	15	68	72	221	10½	291	354	488
50	...	...	50	17	108	193	317	15	62	70	239	10½	247	287	351
50	50	...	...	17	154	222	323	15	82	107	316	10½	440	408	542
50	...	50	...	17	150	210	344	15	78	88	290	10½	309	336	438
25	25	25	25	17	125	183	302	15	74	68	250	10½	279	337	447
	Crushed	quartz.													
40	...	60	...	16	179	256	3 mos. 355	14	93	100	3 mos. 142	9½	257	331	3 mos. 351

MEMORANDA.—All proportions and percentages determined by weight.
Natural sand used, first passed through No. 8 screen and residue excluded.
No. 30 sand passed No. 20 screen and caught on No. 30 screen.
No. 20 sand passed No. 8 screen and passed on No. 20 screen.
No. 100 sand passed No. 30 screen and caught on No. 100 screen.
"Fine" is clean white sand sifted through the No. 100 screen.

TABLE SHOWING TENSILE STRENGTH OF CEMENTS MIXED NEAT WITH DIFFERENT PROPORTIONS OF WATER.

Cement brand.	Water per cent.	Sieve test; residue on.			Wire; minutes.		Tensile strength.					
		No. 50.	No. 100.	No. 180.	Light.	Heavy.	24 hours.	7 days.	28 days.	3 months.	6 months.	12 months.
"Giant" Portland.	13											
	14											
	15	0.15	5.4	21.2	12	207	371	655	875	941	720	787
	16	...	...	...	29	297	303	750	973	1008	735	816
	18	...	...	...	80	355	260	649	773	831	645	748
	20	...	...	...	142	402	233	500	693	716	621	676
	22	...	...	...	268	473	184	546	635	658	601	589
	24	...	...	...	327	912	167	539	649	644	629	755
"Union" Natural.	23	0.1	4.6	10.2	13	32	212	251	252	311	275	356
	24											
	25	...	...	...	18	39	185	218	215	289	300	341
	27	...	...	...	21	42	150	188	220	257	272	314
	29	...	...	...	20	52	128	178	202	246	248	256
	31	...	...	...	21	57	112	173	199	224	259	309
	33	...	...	...	27	85	104	172	182	267	246	290
	35	...	...	...	38	137	93	121	178	260	286	319
	37	...	...	...	34	160	85	108	168	262	306	326
	39	...	...	...	67	233	85	119	202	252	371	400
"Atlas" Portland.	13	0.1	7.0	18.0	13	270	366	775	859	1067	892	832
	14	...	...	...	18	303	404	780	891	972	852	781
	15											
	16	...	...	...	22	327	363	602	725	844	806	723
	18	...	...	...	15	383	308	570	723	785	728	724
	20	...	...	...	56	703	225	590	718	760	674	636
	22	...	...	...	52	833	166	554	649	731	643	604
	24	...	...	...	188	918	42	510	691	695	632	574
"Hoffman" Rosendale.	23	2.3	12.4	21.9	22	59	138	177	271	332	284	264
	24	...	...	...	...	78	125	141	264	342	309	310
	25	...	...	...	35	120	150	164	216	308	318	321
	27	...	...	...	49	143	117	116	194	305	345	272
	29	...	...	...	76	166	96	105	164	272	320	267
	31	...	...	...	117	212	72	72	159	270	371	225
	33	...	...	...	115	235	62	71	147	277	379	244
	35	...	...	...	127	400	50	64	112	245	318	315
	37	...	...	...	198	828	59	62	96	...	284	351
	39	...	...	...	260	1057	54	56	85	...	355	364

MEMORANDA.—Results shown are the averages of six briquettes made.

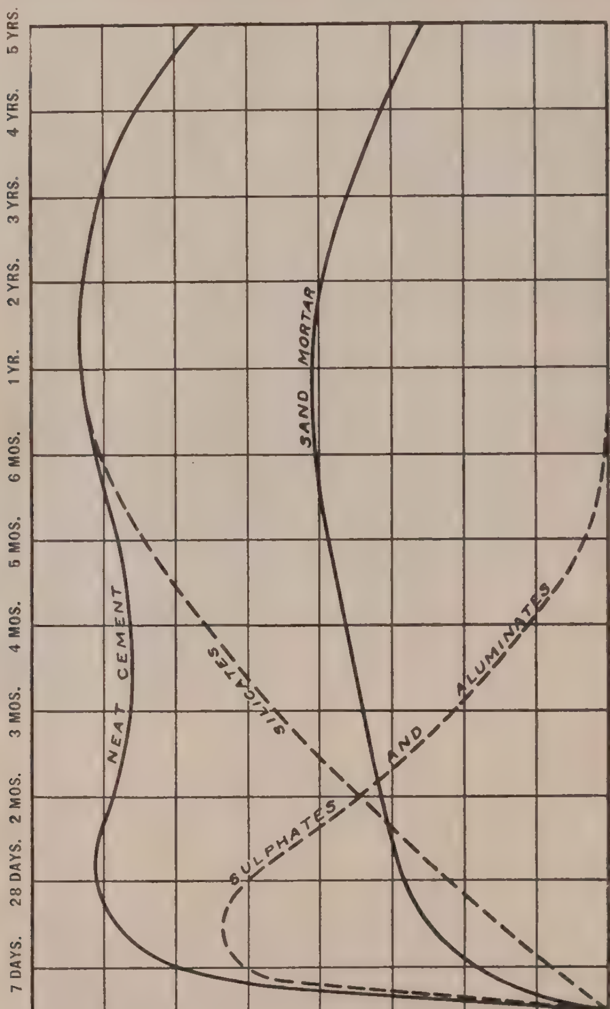
DISCUSSION.

W. K. HATT.—In testing cement one is apt to be disconcerted by the fact that tests at 28 days or at later periods often show a somewhat lower tensile strength, especially in the case of neat mixtures, than the results of tests at earlier periods. This difficulty has been attributed to actual diminution of strength due to a particular stage of hardening of the cement, and also to the action of the water in leaching out the cement from the small test specimens used. I am inclined to think, however, that the imperfections of the ordinary testing apparatus are quite sufficient to account for the phenomenon. It is a well-known fact that the effect of the mechanical imperfections of the gripping apparatus is much more serious in the case of brittle materials of short lengths, and the effect of the imperfections of the gripping apparatus in diminishing the strength of the briquettes would naturally be more serious in the case of the more brittle briquettes which are tested at a later period. As far as the writer knows, this dropping off of the strength is not noticed in the case of sand briquettes. Mr. Hatt.

W. P. TAYLOR.—The fact stated by Prof. Hatt that a brittleness is developed in old briquettes is well recognized, and is clearly shown in the diagrams of long-time tests made in the Philadelphia Laboratory, which are based on the values obtained from upward of 125,000 briquettes. The curves of strength invariably begin to fall off after a period of one or two years and steadily decrease up to at least ten years. It must be stated, however, that this loss of strength is not due to unsoundness, for the reason that this falling off is not apparent in compression tests. It is probable, therefore, that the cause of this action is that the cement becomes brittle, and that any slight eccentricities of loading or irregularities in the bearing surfaces causes eccentric stresses that rupture the briquette at an abnormally low value, such stresses being, of course, much more injurious to a brittle material. Mr. Taylor.

Another fact regarding strength curves that is not generally

Mr. Taylor. known is that there is almost always a depression in the neat cement curve at a period of from 28 days to 6 months, as shown in the accompanying diagram. This effect is probably due to



Typical curve, showing the hardening of Portland cement, measured by tensile strength.

the different rates of hardening of the different constituents of the cement. The sulphates and aluminates harden very rapidly for a short period, and then soon fall to a very low value. The silicates, on the contrary, harden much more slowly, but their action progresses regularly with age. A combination of these ingredients, therefore, will evidently give a curve having a double inflexion, and all the records published seem to bear out this fact. The diagram rather crudely illustrates the idea. It is not intended to show actual values, or the relative magnitude of one of the dotted curves to the other. Mr. Taylor.

The typical curve of tensile strength of Portland cement is then one which rises sharply up to about 28 days, then falls off slightly until from 2 to 6 months, then increases up to 1 or 2 years, and then falls off again as brittleness develops. In the curves of sand mortars the sag in the curve at 3 months is rarely seen, but the falling off of the long-time briquettes is similar to that observed in neat cement.

Cements made in the dome kiln do not show the first falling off to as great an extent as those made in the rotary kiln, but both show the second falling off equally.

TESTS ON THE COMPRESSIVE STRENGTH OF CONCRETE AND MORTAR CUBES.

By C. H. Umstead.

It has been known to the writer for eight years that many thousands of tons of the finer grades of stones from the crushers all over the country were being rejected by engineers as an objectionable material for use in concrete walls and foundations, and that sand was used in preference, at greatly increased cost. A search was made to ascertain whether or not tests had ever been made with this discarded product from the crushers, when mixed with varying proportions of sand and cement. As no such reports could be found, the writer undertook the preparation of seventy-two 3-inch cubes, with varying proportions of crushed stone, which was going to the waste dump as unfit for foundation work, and quartz sand, and submitted them to a crushing-test at periods of fourteen and twenty-eight days. The cement used was in all cases a standard brand of American Portland much used on public works for the past ten years.

The complete test embodied eight operations:

1. Ascertaining the weight per cubic foot of each of the materials used.

2. Ascertaining the specific gravity of each sample.

3. Ascertaining the presence of voids in each material.

4. Ascertaining the theoretical as well as the real volume of each sample.

5. Making seventy-two 3-inch cubes, by mixing the materials in varying proportions with a constant proportion of Portland cement, *all by weight*.

6. Measuring the volume and weight of each cube as received from the molds, also just previous to placing it in the testing machine.

7. Determining the percentage of residue of each material upon five sieves ranging from ½-inch mesh to No. 30, inclusive.

8. Testing the neat Portland cement for tensile strength, for fineness and specific gravity.

MATERIALS USED.

Cement. American Portland, in bags and barrels, and considered in these calculations as weighing 90 pounds per bag and four bags per barrel. The tensile strength per square inch at the end of one day, seven days, and twenty-eight days was 373 pounds, 712 pounds, and 776 pounds per square inch, each value representing the mean of five tests.

Sample No. 1. *Sand.* Plumb Island, near Newburyport, on Merrimac River. This was used as it was unloaded from the barge and dried in the sun. The proportions of voids and fineness are shown in the attached table.

Sample No. 2. *Sand.* This sand was taken from the same locality as above, but from a different barge to test for uniformity in fineness.

Sample No. 3. *Crushed Granite.* This sample was taken after leaving the ½-inch revolving screen at the crusher plant.

Sample No. 4. *Crushed Granite.* This sample is the same as sample No. 3, with the exception that the fine powder has been removed by a blower as it fell from the ½-inch revolving screen at the crusher plant.

Sample No. 5. *Crushed Granite.* This sample is the same as sample No. 3, with the exception that the fine powder has been washed out instead of going through the "blower process." This sample was dried for two days in a kiln before testing.

Sample No. 6. *Crusher Dust.* This sample is the granite dust removed by a blower from the crushed granite described above as sample No. 3.

MIXING AND MOLDING.

Measures. Two white-pine boxes, 12 x 12 x 12 inches inside dimensions, to determine voids and weights per cubic foot for all six samples.

Molds. One gang of six molds, 3 x 3 x 3 inches, made of 1¼-inch white pine, with adjustable 1¼-inch pine partitions, well soaked with shellac and bolted at each end and at the center with 3½-inch carriage bolts.

Two lots of cubes were made each day; it was not safe to remove them at shorter intervals. Two men usually made the cubes, one mixing the material as the other rammed the mixture by striking on a 2-inch square oak block with a hammer until a quaking effect was produced at the surface, and then trowelling to a smooth surface. Before placing the cubes in the testing-machine, the upper and lower faces were covered with a soft coating of gypsum or plaster of Paris.

In none of the mixtures shown in the table attached did it appear that an excess of mortar was being produced, and after removal from the molds many of the cubes appeared very rough on the surfaces.

RESULTS.

TABLE I.

Percentages of samples passing the various sieves.

No. of sieve.	No of sample. 1	2	3	4	5	6
½	100 per ct.	100 per ct.	100 per ct.	100 per ct.	100 per ct.	100 per ct.
14	60.5 "	...	29.5 "	15 "	13.5 "	77 "
20	20 "	30 "	21 "	9.5 "	8 "	62 "
30	...	3 "	14 "	5.5 "	4.5 "	47.5 "

TABLE II.

Voids, weight, and specific gravity of the six samples used.

	No. of sample. 1	2	3	4	5	6
Percentages of voids	36	36	40	46	36	25
Pounds per cubic foot	102	94	95	88	98	88
Specific gravity	2.6	2.6	2.7	2.7	2.7	2.7

Six cubes were prepared from each of twelve mixtures of the proportions shown in Table III. Of each set of six cubes, three were tested at the age of fourteen days, and three at the age of twenty-eight days. The average compressive strength obtained for each of these smaller sets of three cubes also appears in Table III. These tests were made on an Olsen universal testing machine of 100,000 pounds' capacity.

TABLE III.

No. of Mixture.	No. of samples.						Portland Cement	Water.	Compressive strength. Pounds per sq. inch.	
	Sand.		Crusher Refuse.							
	1	2	3	4	5	6			14 days.	28 days.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	oz.		
1	...	8.5	...	...	...	...	4.5	16	2,850	3,670
2	6	...	...	...	3	...	4.5	16	3,120	5,050
3	6	...	...	3	...	...	4.5	16	3,590	4,930
4	5	...	...	...	5	...	5	16	3,260	4,210
5	5	...	...	5	...	..	5	16	3,480	4,500
6	5	...	5	...	...	...	5	20	3,830	4,070
7	3	...	...	...	6	...	4.5	16	3,420	4,970
8	3	...	...	6	...	...	4.5	18	3,620	5,250
9	3	...	6	...	...	...	4.5	18	3,170	4,950
10	...	...	...	...	6	3	4.5	20	2,480	3,370
11	...	...	...	6	...	3	4.5	20	2,920	3,890
12	...	...	6	...	...	3	4.5	22	2,210	2,910

NOTE.—Each value in last two columns represents the average of three tests.

Referring to Table III., mixture No. 1 of sand and cement, in the proportion of (about) 2 to 1 by weight, is the one commonly used on public works as mortar to be combined with broken stone for concrete walls, foundations, locks, etc. Its average compressive strength at twenty-eight days is seen to be 3670 pounds, as against 5050 pounds for mixture No. 2, in which 2.5 pounds of sand were replaced by 3 pounds of finely-crushed granite (sample No.5). It is seen that in the successive mixtures up to No. 9 the amount of sand decreases and that of stone increases progressively. Comparing the crushing strength for these various mixtures (Nos. 2 to 8, inclusive) with that found for mixture No. 1, it is seen that the withdrawal of the sand is a benefit until at least two-thirds by weight has been replaced by crusher refuse.

Mixtures Nos. 10, 11, and 12 were made without sand, but with very fine crusher dust mixed with twice its weight of small crushed stones taken from the refuse of the crusher. The results are little lower than those for mixture No. 1, in which sand was used without stones, and show that a great saving can be made in the construction of large buildings requiring concrete foundations, where sand is hard to find and transportation rates too high to allow hauling from more favorable locations.

Table IV. contains the results obtained from tests made to ascertain the relative tensile strength of 1 to 2 mortar briquettes made from Samples Nos. 1 and 6 with Portland cement. The

water added was in proportions of 10 per cent. by weight. The figures in parentheses indicate the number of tests averaged:

TABLE IV.

Tensile strength, in pounds per squre inch, of 1 to 2 mortar briquettes.

No. of sample.	7 days.	14 days.	28 days.
1	292 (25)	308 (7)	394 (10)
6	366 (10)	440 (5)	486 (25)

The results in Table IV. do not agree with the conclusions of Mr. Feret as presented before the International Maritime Congress, in London, in 1893: "That it is necessary to use about twice as much cement with fine sand as with coarse to obtain the same strength of mortar."

In the light of these seemingly opposite results, it can only be inferred for the present that sample No. 6, "crusher dust," has an inherent cementing quality of its own, not found in ordinary sand, nor in that used by Mr. Feret, and that further tests should be conducted. It is a well-known fact that the "run-off" from a newly surfaced road, after a moderate rain-storm, will often fill up and cement the voids in the loose stones near the edges of the roadway.

According to the records of the United States Geological Survey, there were produced in the United States, in the year ending June 30, 1901, over 20,000,000 barrels of cement. For concrete of the usual proportions in public works, 1⅓ barrels of cement are required for one cubic yard of concrete. The annual consumption of sand would be 10,000,000 cubic yards, provided it be mixed with stone or gravel in proportion of 2 to 3. A cubic yard of sand at the most favored locations costs fifty cents delivered on the work. Assuming that only one-half of the yearly production of cement was used in making concrete in all its forms, then at least $2,500,000 was the amount of money involved in a single year in the decisions of those who used an inferior article in the form of sand rather than the fine materials from the crushers at comparatively little expense.

CHARTER

OF THE

AMERICAN SOCIETY FOR TESTING MATERIALS.

To the Honorable the Judges of the Court of Common Pleas No. 2 *in and for the City and County of Philadelphia: of March Term,* 1902, *No.* 2056:

In compliance with the requirements of an Act of the General Assembly of the Commonwealth of Pennsylvania, entitled "An Act to Provide for the Incorporation and Regulation of Certain Corporations," approved the 29th day of April, A.D. one thousand eight hundred and seventy-four, and the supplements thereto, the undersigned, Henry M. Howe, Charles B. Dudley, Edgar Marburg, Robert W. Lesley, Mansfield Merriman, Albert Ladd Colby and William R. Webster, six of whom are citizens of Pennsylvania, having associated themselves together for the purposes hereinafter set forth, and desiring that they may be incorporated according to law, do hereby certify:

1. The name of the proposed corporation is the "AMERICAN SOCIETY FOR TESTING MATERIALS."

2. The corporation is formed for the Promotion of Knowledge of the Materials of Engineering, and the Standardization of Specifications and the Methods of Testing.

3. The business of the said corporation is to be transacted in Philadelphia.

4. The said corporation is to exist perpetually.

5. The names and residences of the incorporators are as follows:

HENRY M. HOWE, 27 West Seventy-third Street, New York.
CHARLES B. DUDLEY, Altoona, Pa.
EDGAR MARBURG, 517 South Forty-first Street, Philadelphia.
ROBERT W. LESLEY, 22 South Fifteenth Street, Philadelphia.
MANSFIELD MERRIMAN, South Bethlehem, Pa.
ALBERT LADD COLBY, South Bethlehem, Pa.
WILLIAM R. WEBSTER, "The Bartram," Thirty-third and Chestnut Streets, Philadelphia.

6. The management of the said corporation shall be vested in an Executive Committee, consisting of six (6) members, viz.: the Chairman, the Vice-Chairman, the Secretary, the Treasurer and two other members of the corporation, and such other officers as the corporation may from time to time appoint.

7. The corporation has no capital stock, and the members thereof shall be composed of the subscribers and their associates and of such persons as may from time to time be admitted by vote in such manner and upon such requirements as may be prescribed by the By-Laws. The corporation shall nevertheless have power to exclude, expel or suspend members for just or legal cause, and in such legal manner as may be ordained and directed by the By-Laws.

8. The By-Laws of this corporation shall be admitted and taken to be its laws subordinate to the statute aforesaid; this Charter; Constitution and Laws of the Commonwealth of Pennsylvania, and the Constitution of the United States; they shall be altered and amended as provided for by the By-Laws themselves; and shall prescribe the powers and functions of the Executive Committee herein mentioned and those to be hereafter elected, the times and places of meetings of the Committee and this corporation; the number of members who shall constitute a quorum at the meetings of the corporation, and of the Committee; the qualifications and manner of electing members; the manner of electing officers; and the powers and duties of such officers; and all other concerns and internal arrangements of the said corporation.

Witness our hands and seals this twenty-first day of March, A.D. 1902.

(Signed)
EDGAR MARBURG,
R. W. LESLEY,
WM. R. WEBSTER,
MANSFIELD MERRIMAN,
ALBERT LADD COLBY.

BY-LAWS.

(Adopted June 12, 1902.)

Article I.

MEMBERS.

Section 1. Any person, corporation or technical society holding membership in the International Association for Testing Materials is eligible for membership.

Sec. 2. Any person, corporation or society can become a member of this Society and of the International Association for Testing Materials simultaneously upon being proposed by two members of this Society and being approved by its Executive Committee.

Sec. 3. Any member who subscribes annually the sum of fifty dollars ($50) toward the general funds of the Society shall be designated a Contributing Member, his rights and privileges as a member remaining unchanged.*

Sec. 4. Applications for membership and resignation from membership must be transmitted in writing to the Secretary.

Article II.

OFFICERS AND THEIR ELECTION.

Section 1. The officers shall be a President, Vice-President, Secretary and Treasurer.

Sec. 2. The offices of Secretary and Treasurer shall be held by the same person.

Sec. 3. These officers shall be elected by letter-ballot, at the Annual Meeting, and shall hold office for two years.

Sec. 4. The Executive Committee shall consist of these officers and also the last past-President and three members, two being elected by letter-ballot at each Annual Meeting in the odd years and one at each Annual Meeting in the even years.

Sec. 5. The President shall be, *ex officio*, the nominee for American Member of the Council of the International Association.

Sec. 6. The Secretary shall receive a salary to be fixed by the Executive Committee.

* The Executive Committee has ruled that Contributing Members shall be exempt from the regular membership dues.

SEC. 7. The officers and members of the Executive Committee of this Society to hold office until the next election under these By-Laws, shall be as follows: To hold office for two years—President, Charles B. Dudley; Vice-President, R. W. Lesley; Secretary-Treasurer, Edgar Marburg; members of the Executive Committee, Henry M. Howe and James Christie. To hold office for one year—members of the Executive Committee, Albert Ladd Colby and John McLeod.

SEC. 8. The above officers and members of the Executive Committee, as well as all succeeding officers and members of the Executive Committee elected under these By-Laws, shall serve for the respective terms to which they shall have been elected, or until their successors shall have been duly elected.

SEC. 9. The Executive Committee shall have the power to fill any vacancies occurring in their number by death, resignation or otherwise.

SEC. 10. The election of officers and members of the Executive Committee shall be by letter-ballot. The Executive Committee, before each Annual Meeting, shall appoint a Nominating Committee, whose duty it shall be to nominate a full list of officers. The list of nominations so made shall be submitted to the membership not more than eight (8) nor less than four (4) weeks before the coming Annual Meeting.

Further nominations, signed by at least ten (10) members, may be submitted to the Secretary in writing at least four (4) weeks before the Annual Meeting, and such nominations shall also be submitted to the membership on the official ballot.

ARTICLE III.

MEETINGS.

SECTION 1. The Society shall meet annually. The time and place of each meeting shall be fixed by the Executive Committee.

SEC. 2. Special meetings may be called whenever the Executive Committee shall deem it necessary, or upon the request in writing to the President of twenty-five (25) members.

ARTICLE IV.

DUES.

SECTION 1. The fiscal year shall commence on the first of January, and all dues shall be payable in advance.

SEC. 2. The annual dues of each member shall be $3.00. Of this amount $1.50 shall be transmitted by the Secretary to the International Association for Testing Materials. The remainder shall be applied to the treasury of the Society.

SEC. 3. Any member of the Society whose dues shall remain unpaid for the period of one year shall forfeit the privileges of membership. If he neglects to pay his dues within thirty days thereafter, and after notification from the Secretary, his name may be stricken from the roll of membership by the Executive Committee.

ARTICLE V.

AMENDMENTS.

SECTION 1. Proposed Amendments to these By-Laws, signed by at least three members, must be presented in writing to the Executive Committee at least four weeks before the next Annual Meeting. In the notices for this meeting the proposed Amendments shall be printed. At the Annual Meeting the proposed Amendment may be discussed and amended and may be passed to letter-ballot by a two-thirds vote of those present.

If two-thirds of the votes obtained by letter-ballot are in favor of the proposed Amendment, it shall be adopted.

SEC. 2. The Executive Committee is authorized to number the Articles and Sections of the By-Laws to correspond with any changes that may be made.

RULES GOVERNING THE EXECUTIVE COMMITTEE.

1. Regular meetings shall be held on the first Saturday in January, April, July and October. Four members shall constitute a quorum.

At each meeting the Secretary shall report the names of all new members and of members who have resigned during the previous quarter, and shall present a financial statement.

At the January meeting the Secretary shall report the names of all members whose dues are unpaid.

The accounts of the Secretary shall be duly audited at the middle and close of each fiscal year, and the report of the auditors shall be presented in writing at the July and January meetings.

2. Special meetings may be held at any time at the call of the President, or upon the written request of four members of the Executive Committee. The notice for such meetings shall be mailed by the Secretary at least one week in advance of the meeting, and the business shall be stated in the notice.

3. The Secretary shall transmit to the International Association within five days after the first day of January, April, July and October $1.50 for each member whose dues were paid in the previous quarter together with the names of those members.

No other expenses shall be paid except on vouchers certified to be correct by the Chairman of the Committee on Finance, or a member thereof designated by the Chairman.

GENERAL INFORMATION.

International Association for Testing Materials.

Historical.—The International Association for Testing Materials had its origin in a conference of a small group of workers in experimental engineering held in Munich in 1882, at the instance chiefly of the late John Bauschinger. Meetings on a larger scale were subsequently held in Dresden (1884), Berlin (1886), Munich (1888), Vienna (1893) and Zurich (1895). At the Zurich Congress the International Association for Testing Materials was formally organized, the Second Congress was held at Stockholm in 1897, the Third Congress met at Buda-Pesth in 1901,* the Fourth Congress will assemble at St. Petersburg August 18–24, 1904, and succeeding congresses will be convened biennially thereafter.

Membership.—The membership, according to the latest official report (February, 1904), is distributed as follows: United States, 399;† Germany, 367; Russia, 364; Austria, 193; France, 154; Switzerland, 82; Hungary, 80; Belgium, 53; England, 52; Italy, 50; Sweden, 49; Denmark, 48; Holland, 45; Norway, 44; Spain, 14; Portugal, 11; Servia, 5; Luxemburg, 4; Australia, 2; Brazil, 2; Roumania, 2; Argentine Republic, 1; Chili, 1. Total, 2022, representing 23 countries.

Objects.—The objects of the Association, as set forth in its By-Laws,‡ are: "The development and unification of standard methods of testing; the investigation of the technically important properties of the materials of construction and other materials of technical importance, and also the perfecting of apparatus used for that purpose."

The important subject of specifications has, however, also been included within the scope of the Association's activity. Thus, International Committee No. 1 has been charged to report on the following problem: "On the basis of existing specifications, to seek methods and means for the introduction of international

* The Third Congress, originally scheduled for 1900, to be held at Paris during the Exhibition, was abandoned in order not to conflict with the International Testing Congress, conducted under French auspices.

† The American membership is now (March, 1904) 429.

‡ These By-Laws are given in full on pp. 471–473.

specifications for testing and inspecting iron and steel of all kinds."

Again, in pursuance of American initiative at the Buda-Pesth Congress (1901), Committee No. 1 has been enlarged by the addition of three American members, with a view of reporting on "Standard International Specifications for Cast Iron and Finished Castings," and Committee No. 22 has been instructed to report "On the Feasibility of the Establishment of Standard International Specifications for Cements."

Administration.—The affairs of the Association are administered by a Council, consisting of the President and one representative (member of Council) from each country having a membership of twenty (20) or more.

Methods.—The original plan was to conduct investigations almost exclusively through the agency of international committees. These committees proved unwieldy, however, by reason of their large membership, with the added difficulties arising from geographical separation and differences of language. In pursuance of resolutions at the Buda-Pesth Congress (1901) the Council has discharged some of these committees, reassigning the problems in part to individual referees.* In the case of questions of direct international concern the original international committees are continued.

At the international congresses the reports of these committees as well as individual contributions by members are presented and discussed.

Publications.—On May 5, 1896, the International Council effected an arrangement with the publishers of *Baumaterialenkunde*† (Materials of Construction) by which that journal became the official organ of the Association. Since July, 1896, this journal has published the Proceedings of Congresses and other official matter in German and French. The fact that the Association did not furnish printed Proceedings to members free of charge, and that no provision had been made for translation into English, gave rise to no little dissatisfaction. At the Buda-Pesth Congress (1901) the International Council was accordingly authorized to perfect a new arrangement by which all official matter is now

* For complete list of problems, committees and referees, see pp. 474–480.

† *Baumaterialenkunde:* Published bi-weekly at Stuttgart, Germany, in German and French. Regular subscription price $3.50 per annum; special terms to members of the International Association for Testing Materials, $2.50 per annum. Address: Staehle & Friedel, No. 57 Tuebinger Street, Stuttgart, Germany.

published in three separate editions (German, English and French) and sent free of charge to every member of the Association in whatever language is preferred.

ORGANIZATION OF THE AMERICAN MEMBERS OF THE INTERNATIONAL ASSOCIATION.

Historical.—With a view of bringing the members of like nationality into closer relations among themselves, and in order to simplify the management and render the work of the Association more effective, it was decided at the Stockholm Congress (1897) to encourage the consolidation of the membership in the various countries into separate national organizations. In pursuance of this action the American members met in Philadelphia on June 16, 1898, and organized under the name of the "American Section of the International Association for Testing Materials."

In March, 1902, the Executive Committee of the American Section applied for a Charter under the laws of the State of Pennsylvania for purposes of incorporation under the proposed new name of the "American Society for Testing Materials." This Charter was duly granted, and at the Fifth Annual Meeting, held at Atlantic City, N. J., it was unanimously adopted on June 12, 1902.

Objects.—The objects of the Society are essentially identical with those of the International Association, with which it stands in direct organic relation, both through its membership in the same as a body, and through the prescribed individual membership on the part of every one of its members.

As stated in the Charter: "The corporation is formed for the promotion of knowledge of the materials of engineering, and the standardization of specifications and the methods of testing."

Representation on the International Council.—The American members are entitled to one representative on the International Council. By the new Statutes of the Association (1901): "the members of Council shall be proposed by the members of each country; their final appointment being confirmed by the Congress." According to the By-Laws of the American Society the President becomes, "*ex officio*, the nominee for American Member of the Council of the International Association."

Meetings.—The Society meets annually at a time and place fixed by the Executive Committee. Special meetings may also be called in accordance with the provisions of the By-Laws.

Annual meetings have been held in past years as follows:

First Annual Meeting, Philadelphia, Pa., House of Engineers' Club of Philadelphia, August 27, 1898.

Second Annual Meeting, Pittsburg, Pa., Rooms of Engineers' Society of Western Pennsylvania, August 15, 16, 1899.

Third Annual Meeting, New York, N. Y., House of American Society of Mechanical Engineers, October 25, 26, 27, 1900.

Fourth Annual Meeting, Niagara Falls, N. Y., International Hotel, June 29, 1901.

Fifth Annual Meeting, Atlantic City, N. J., Hotel Traymore, June 12, 13, 14, 1902.

Sixth Annual Meeting, Delaware Water Gap, Pa., Hotel Kittatinny, July 1, 2, 3, 1903.

Membership.—The number of American members at the time of the organization meeting in 1898 was 70. The membership reported at the successive annual meetings was as follows: (1899) 128, (1900) 160, (1901) 168, (1902) 175, (1903) 340, and it is now (March, 1904), 429.

Methods.—The operations of the Society are conducted in part under the auspices of the International Association and in part independently.

The number of American representatives on international committees is fixed by the International Council. These American sub-committees are authorized, however, to increase their number at pleasure, subject always to the approval of the Executive Committee of the American Society. The sense of these enlarged sub-committees on all questions is determined by majority vote; but on the international committees the representation and the number of votes allowed remain as originally fixed by the International Council.

The American Society appoints other committees at its discretion entirely independently of the International Association. The policy is to accord equal numerical representation on such committees to engineers (or scientists) and to manufacturers.

The Committees of the American Society are now as follows:

A. On Standard Specifications for Iron and Steel.

B. On Standard Specifications for Cast Iron and Finished Castings.

C. On Standard Specifications for Cement.

D. On Standard Specifications for Paving and Building Brick.

E. On Preservative Coatings for Iron and Steel.

F. On Heat Treatment of Iron and Steel.

G. On the Magnetic Properties of Iron and Steel.
H. On Standard Tests for Road Materials.
I. On Steel-Concrete.
J. On the Corrosion of Metals.

Publications.—The publications of the Society appeared originally at irregular intervals in the form of bulletins. Twenty-eight (28) bulletins, containing a total of 266 pages, were thus issued. In 1902 it was decided to publish the Proceedings thereafter in the form of annual volumes. The first of these volumes, designated Volume II. of the Proceedings, contains 388 pages, the Bulletins previously issued constituting Volume I.*

A notable work accomplished by the Society is the framing, by the American Branch of International Committee No. 1 (enlarged for this purpose to thirty-four members) and the adoption in August, 1901, by letter-ballot of the Society, of Standard Specifications on (1) Structural Steel for Bridges and Ships, (2) Structural Steel for Buildings, (3) Open-hearth Boiler Plate and Rivet Steel, (4) Steel Rails, (5) Steel Splice Bars, (6) Steel Axles, (7) Steel Tires, (8) Steel Forgings, (9) Steel Castings, (10) Wrought Iron. These ten Standard Specifications are published separately in the order given as Bulletins Nos. 8 to 16 inclusive, and Bulletin No. 24.

* Bulletins Nos. 1, 2 and 3 are out of print. Bulletins Nos. 4 to 28, inclusive, may be had on application to the Secretary at the price of ten cents (10) each. The price of the annual volumes is three dollars ($3), postage prepaid. For Table of Contents of previous publications, see pp. 466–469.

OFFICERS

OF THE

AMERICAN SOCIETY FOR TESTING MATERIALS.

PRESIDENT,

CHARLES B. DUDLEY.

VICE-PRESIDENT,

R. W. LESLEY.

SECRETARY-TREASURER,

EDGAR MARBURG.

Office : University of Pennsylvania, Philadelphia, Pa.

MEMBERS OF THE EXECUTIVE COMMITTEE :

Term Expiring in 1904.

JAMES CHRISTIE, HENRY M. HOWE.

Term Expiring in 1905.

ALBERT LADD COLBY, JOHN MCLEOD.

STANDING COMMITTEES.

COMMITTEE ON FINANCE.

JOHN MCLEOD, *Chairman*, ALBERT LADD COLBY,
R. W. LESLEY.

COMMITTEE ON MEMBERSHIP.

JAMES CHRISTIE, *Chairman*, R. W. LESLEY,
EDGAR MARBURG.

COMMITTEE ON PUBLICATIONS.

HENRY M. HOWE, *Chairman*, ALBERT LADD COLBY,
EDGAR MARBURG.

LIST OF MEMBERS

OF THE

AMERICAN SOCIETY FOR TESTING MATERIALS.

[Affiliated with the International Association for Testing Materials.]

ELECTED

1902. ACKERMAN, ERNEST R., President, Lawrence Cement Company, 1 Broadway, New York, N. Y.

1904. ADAMS, HUGH W. Eastern Agent, Sloss-Sheffield Steel and Iron Company, 15 Beekman Street, New York, N. Y.

1898. AERTSEN, GUILLIAEM, General Manager, Latrobe Steel Company, 1200 Girard Building, Philadelphia, Pa.

1902. AIKEN, W. A. General Inspector of Material, Rapid Transit Railroad Commission of New York, 613 Empire Building, Pittsburg, Pa.

1902. AJAX METAL COMPANY. G. H. Clamer, Second Vice-President and Secretary, 46 Richmond Street, Philadelphia, Pa.

1903. ALLEN, A. W. Superintendent, Steel Department, Pencoyd Iron Works, 267 Rochelle Avenue, Philadelphia, Pa.

1902. ALLEN, FRANCIS B. Mechanical Engineer; Second Vice-President, Hartford Steam Boiler Inspection and Insurance Company, Hartford, Conn.

1902. AMERICAN BRIDGE COMPANY. C. C. Schneider, Consulting Engineer, Fifteenth and Chestnut Streets, Philadelphia, Pa.

1898. AMERICAN FOUNDRYMEN'S ASSOCIATION. Richard G. Moldenke, Secretary, P. O. Box 432, New York, N. Y.

1897. AMERICAN SOCIETY OF MECHANICAL ENGINEERS. F. R. Hutton, Secretary, 12 West Thirty-first Street, New York, N. Y.

1900. AMERICAN STEEL AND WIRE COMPANY. F. H. Daniels, Chief Engineer, Worcester, Mass.

1899. ANDERSON, FREDERICK PAUL. Dean of School of Mechanical Engineering, State College of Kentucky, Lexington, Ky.

1896. ANDERSON, J. W. Carbon Steel Company, Pittsburg, Pa.

1897. ANDERSON, R. WILSON. Superintendent, Open-Hearth Plant, Carbon Steel Company, Pittsburg, Pa.

1902. ARNOLD, CHARLES E. Chief Chemist, Dominion Iron and Steel Company, Sydney, C. B., Canada.

1903. ATKINSON, EDWARD. Director, Insurance Engineering Station, 31 Milk Street, Boston, Mass.

ELECTED

1902. BAILEY, J. B. Treasurer and General Manager, Central Iron and Steel Company, Harrisburg, Pa.

1903. BAKENHUS, R. E. Civil Engineer, United States Navy, Naval Training Station, Newport, R. I.

1903. BAKER, IRA O. Professor of Civil Engineering, University of Illinois, Champaign, Ill.

1898. BARBOUR, FRANK A. Civil Engineer, Snow and Barbour, 1121 Tremont Building, Boston, Mass.

1902. BARTOL, GEORGE E. President, Dexter Portland Cement Company, 232 The Bourse, Philadelphia, Pa.

1904. BASQUIN, OLIN H. Associate Professor of Physics, Northwestern University, Evanston, Ill.

1903. BASSETT, WILLIAM H. Chemist in charge of Laboratories, Coe Brass Manufacturing Company, Torrington, Conn.

1903. BATEMAN, F. W. Civil Engineer, Clinton, Mass.

1903. BECKETT, JAMES A. General Superintendent, Walter A. Wood Mower and Reaper Company, Hoosick Falls, N. Y.

1903. BENTLEY, ROBERT. Secretary and General Manager of the Ohio Iron and Steel Company, Lowellville, O.

1903. BERG, WALTER G. Chief Engineer, Lehigh Valley Railroad, 261 West Fifty-second Street, New York, N. Y.

1902. BERGER, BERNT. Civil Engineer, Assistant Engineer to Theodore Cooper, 35 Broadway, New York, N. Y.

1903. BERRALL, JAMES. Civil Engineer, Bond Building, Washington, D. C.

1898. BETHLEHEM STEEL COMPANY. E. O'C. Acker, Assistant General Superintendent, South Bethlehem, Pa.

1896. BISSELL, GEORGE W. Professor Mechanical Engineering, Iowa State College, Ames, Iowa.

1903. BIXBY, W. H. Major, Corps of Engineers, United States Army. Address unsettled during 1904.

1902. BLISS, COLLINS P. Professor of Mechanical Engineering, and Director of Testing Laboratory, New York University, University Heights, New York, N. Y.

1903. BOCKING, RUDOLPH. Halbergerhutte, Post Brebach, Germany.

1903. BOLLER AND HODGE. Consulting Engineers, 1 Nassau Street, New York, N. Y.

1902. BONZANO, A. President, Bonzano Rail-Joint Company, 331 South Eighteenth Street, Philadelphia, Pa.

1896. BOOTH, GARRETT AND BLAIR. Engineers and Chemists, 406 Locust Street, Philadelphia, Pa.

ELECTED

1902. BOYNTON, C. W. Cement Inspector, Baltimore and Ohio Railroad, Wheeling, W. Va.

1900. BRAINE, L. F. General Manager, Continuous Rail-Joint Company, Newark, N. J.

1898. BRAMWELL, JOSEPH W. Falkenau-Sinclair Machine Company, 109 North Twenty-second Street, Philadelphia, Pa.

1899. BROADHURST, W. H. Chemist, Department of Public Works, Municipal Building, Brooklyn, N. Y.

1903. BROWN, CHARLES CARROLL. Editor, Municipal Engineering Magazine, 408 Commercial Club Building, Indianapolis, Ind.

1903. BRUNNER, JOHN. Assistant General Superintendent, Illinois Steel Company, 1732 Chicago Avenue, Evanston, Ill.

1903. BUCKLEY, E. R. Director, Missouri Bureau of Geology and Mines, State Geologist, Rolla, Mo.

1903. BUDD, H. I. Commissioner of Public Roads of State of New Jersey, Mt. Holly, N. J.

1904. BUNNELL, F. O. Engineer of Tests, Chicago, Rock Island and Peoria Railway, Forty-seventh Street and Wentworth Avenue, Chicago, Ill.

1902. BURDETT, F. A. Civil Engineer, 3 East Thirty-third Street, New York, N. Y.

1903. BURNHAM, RAYMOND. Associate Professor Experimental Engineering, Armour Institute of Technology, Chicago, Ill.

1899. BURR, WILLIAM H. Professor of Civil Engineering, Columbia University, New York, N. Y.

1903. BUZZI, P. D. Superintendent of Engineering Laboratory, Tacon 3, Havana, Cuba.

1902. CAMBIER, JACOB. Chemist, Colorado Fuel and Iron Company, 910 Spruce Street, Pueblo, Colo.

1899. CAMBRIA STEEL COMPANY. George E. Thackray, Structural Engineer, Johnstown, Pa.

1896. CAMPBELL, H. H. Superintendent and General Manager, The Pennsylvania Steel Company, Steelton, Pa.

1903. CAMPBELL, WILLIAM. Metallurgist, Barnard Fellow, Columbia University, New York, N. Y.

1898. CAPP, JOHN A. Engineer, Testing Laboratory, General Electric Company, Schenectady, N. Y.

1898. CARNEGIE STEEL COMPANY. John McLeod, Assistant to President, Pittsburg, Pa.

1903. CARNEY, F. D. Assistant Superintendent, Pennsylvania Steel Company, Steelton, Pa.

ELECTED

1902. CARPENTER, LOUIS G. Professor of Civil and Irrigation Engineering, and Director of Experiment Station, Fort Collins, Colo.

1895. CARPENTER, ROLLA C. Professor Experimental Engineering, Cornell University, 31 Eddy Street, Ithaca, N. Y.

1902. CARR, LOVELL H. General Sales Agent, The Edison Portland Cement Company, 71 Broadway, New York, N. Y.

1899. CARTER, ROBERT A. President, Monongahela Iron and Steel Company, Box 215, Pittsburg, Pa.

1903. CARTLIDGE, C. H. Bridge Engineer, Chicago, Burlington and Quincy Railroad, 209 Adams Street, Chicago, Ill.

1902. CENTRAL IRON AND STEEL COMPANY. James B. Bailey, Treasurer and General Manager, Harrisburg, Pa.

1898. CHRISTIE, JAMES (*Member of Executive Committee*). Chief Mechanical Engineer, American Bridge Company, Pencoyd, Pa.

1900. CHURCHILL, CHARLES S. Chief Engineer, Norfolk and Western Railway, Roanoke, Va.

1900. CLARK, F. H. Mechanical Engineer, Chicago, Burlington and Quincy Railroad, 209 Adams Street, Chicago, Ill.

1904. CLIFTON, CHARLES H. First Assistant, Philadelphia Municipal Testing Laboratory, 318 City Hall, Philadelphia, Pa.

1899. COLBY, ALBERT LADD (*Member Executive Committee*). International Nickel Company, 43 Exchange Place, New York, N.Y.

1899. COLBY, J. ALLEN. Inspecting Engineer, Witherspoon Building, Philadelphia, Pa.

1900. COLORADO FUEL AND IRON COMPANY. C. S. Robinson, General Manager, Iron Department, Denver, Colo.

1900. CONDRON, T. L. Resident Engineer, Pittsburg Testing Laboratory, 1750 Monadnock Building, Chicago, Ill.

1903. COOK, EDGAR S. President, Warwick Iron and Steel Company, Pottstown, Pa.

1899. CORTHELL, E. L. Civil Engineer, 1 Nassau Street, New York, N. Y.

1902. COSBY, SPENCER. Captain, Corps of Engineers, U. S. Engineer Office, Mobile, Ala.

1903. COWEN, HERMAN C. Superintendent Catskill Cement Company, Smith Landing, Greene County, N. Y.

1903. CRESWELL, DAVID S. Iron Founder; The Bartram, Philadelphia, Pa.

1903. CROXTON, H. A. President, Massillon Iron and Steel Company, Massillon, O.

1899. CRUIKSHANK, BARTON. Consulting Engineer, 1813 West Genesee Street, Syracuse, N. Y.

ELECTED

1903. DABBS, HAROLD M. L. J. McCloskey and Company, Thirtieth and Locust Streets, Philadelphia, Pa.

1900. DAVIDSON, GEORGE M. Engineer of Tests, Chicago and Northwestern Railroad, Chicago, Ill.

1903. DAVIS, WILLIAM R. Chief Bridge Designer, State Engineer's Office, Albany, N. Y.

1902. DE ARMOND, W. C. President, Protectus Company, 1103 North American Building, Philadelphia, Pa.

1904. DE WYRALL, CYRIL. Paint and Waterproofing Engineer, 3287 Broadway, New York, N. Y.

1899. DEANS, JOHN STERLING. Chief Engineer, Phœnix Bridge Company, Phœnixville, Pa.

1902. DERLETH, CHARLES, JR. Professor of Structural Engineering, University of California, Berkeley, Cal.

1903. DEVERELL, H. F. Secretary, Otis Steel Company, Cleveland, O.

1903. DIEDERICHS, H. Assistant Professor of Experimental Engineering, Cornell University, 913 North Aurora Street, Ithaca, N. Y.

1903. DILLER, H. E. Chief Chemist, Western Electric Company, Chicago, Ill.

1903. DIMMICK, J. K. 1049 Drexel Building, Philadelphia, Pa.

1902. DIXON CRUCIBLE COMPANY, JOSEPH. Malcolm McNaughton, Superintendent, Paint and Lubricating Department, Jersey City, N. J.

1903. DIXON, R. M. Vice-President, The Safety Car Heating and Lighting Company, 160 Broadway, New York, N. Y.

1901. DOBLE, WILLIAM A. Mechanical Engineer; President, Abner Doble Company, 200 Fremont Street, San Francisco, Cal.

1898. DOW, A. W. Inspector of Asphalts and Cements, District of Columbia, Washington, D. C.

1903. DRAKE, C. F. Western Manager, Crowell, Dickman and Kenyon, Inspecting Engineers, 1120 Rookery Building, Chicago, Ill.

1899. DROWN, THOMAS M. President, Lehigh University, South Bethlehem, Pa.

1903. DRUMMOND, M. J. President, Glamorgan Pipe and Foundry Company, 192 Broadway, New York, N. Y.

1902. DU COMB, W. C., JR. Mechanical Engineer; Engineer of Tests, 1424 North Ninth Street, Philadelphia, Pa.

1896. DUDLEY, CHARLES B. (*President*). Chemist, Pennsylvania Railroad, Altoona, Pa.

ELECTED

1902. DUDLEY, P. H. Consulting Engineer, 80 Pine Street, New York, N. Y.

1901. DUFOUR, F. O. Professor of Bridge Engineering, University of Wisconsin, Madison, Wis.

1902. DUMARY, L. HENRY. President, The Helderberg Cement Company, 38 State Street, Albany, N. Y.

1902. DUNBAR, W. O. Assistant Engineer, Pennsylvania Railroad Testing Department, Altoona, Pa.

1902. EASBY, M. WARD. Consulting Engineer, 909 Crozer Building, Philadelphia, Pa.

1902. EDWARDS, WARRICK R. Assistant to Engineer of Bridges and Buildings, Baltimore and Ohio Railroad, 1039 Calvert Building, Baltimore, Md.

1903. ELDRIDGE, G. F. B. Nicoll and Company, 59 Wall Street, New York, N. Y.

1896. ELY, THEODORE N. Chief of Motive Power, Pennsylvania Railroad, Broad Street Station, Philadelphia, Pa.

1898. ENGINEERING RECORD. 114 Liberty Street, New York, N. Y.

1903. ERLANDSEN, OSCAR. Assistant Engineer, Department of Bridges 32 Sutton Place, New York, N. Y.

1903. ESTERLINE, J. WALTER. Assistant Professor of Electrical Engineering, Purdue University, Lafayette, Ind.

1896. ESTRADA, E. D. Engineer, Department of Public Works, Pinar del Rio, Cuba.

1904. FACKENTHAL, JR., B. F. President, Thomas Iron Company, Easton, Pa.

1903. FACULTY APPLIED SCIENCE, MCGILL UNIVERSITY. Henry T. Bovey, Dean, Montreal, Can.

1900. FAHRIG, ERNST. Chief of Laboratories, Philadelphia Commercial Museums, Philadelphia, Pa.

1902. FALKENAU, A. Engineer and Machinist, 4602 Kingsessing Avenue, Philadelphia, Pa.

1902. FARREL FOUNDRY AND MACHINE COMPANY. Herbert E. Field, Metallurgist, Ansonia, Conn.

1902. FAY, HENRY. Assistant Professor Analytical Chemistry and Metallography, Massachusetts Institute of Technology, Boston, Mass.

1903. FENNER, L. M. Chemist, New York Air Brake Company, 10 Boyd Street, Watertown, N. Y.

1903. FITZGERALD, FRANCIS A. J. Chemical Engineer, P. O. Box 118, Niagara Falls, N. Y.

ELECTED

1899. FLAGG, STANLEY G., JR. Stanley G. Flagg and Company, Nineteenth Street and Pennsylvaina Avenue, Philadelphia, Pa.

1903. FLETCHER, AUSTIN B. Secretary Massachusetts Highway Commission, 20 Pemberton Square, Boston, Mass.

1901. FORREST, C. N. Chemist and Inspector, Long Island Railroad, Long Island City, N. Y.

1903. FORSYTH, WILLIAM. Mechanical Engineer, *Railway Age*, Chicago, Ill.

1898. FRANKLIN INSTITUTE. William H. Wahl, Secretary, 15 South Seventh Street, Philadelphia, Pa.

1903. FRENCH, JAMES B. Bridge Engineer, Atlantic Avenue Improvement, Long Island Railroad, 44 Court Street, Brooklyn, N. Y.

1903. FRENCH, LESTER G. Editor, *Machinery*, 99 Broadway, New York, N. Y.

1903. FULLER, ALMON H. Professor of Civil Engineering, Washington University, University Station, Seattle, Wash.

1903. GALBRAITH, J. Principal, School of Practical Science, Toronto, Can.

1902. GERSTELL, A. F. Vice-President and General Manager, Alpha Portland Cement Company, Alpha, N. J.

1902. GIBBS, A. W. General Superintendent of Motive Power, Pennsylvania Railroad, Altoona, Pa.

1902. GIBBS, GEORGE. First Vice-President, Westinghouse, Church, Kerr and Company, 10 Bridge Street, New York, N. Y.

1903. GILMOUR, EDWARD B. Superintendent Foundry, Acme Harvester Company, 421 Fifth Avenue, Peoria, Ill.

1904. GIROUX, GUSTAVE. Inspector of Materials, Canadian Pacific Railway Company, 5 Craig Street, Montreal, P. Q., Canada.

1904. GLASGOW IRON COMPANY. C. B. Shoemaker, President, 903–908 Harrison Building, Philadelphia, Pa.

1896. GOSS, WILLIAM F. M. Dean of the Schools of Engineering, Purdue University, Lafayette, Ind.

1904. GOWEN, CHARLES S. Engineer, New Croton Dam, Ossining, N. Y.

1903. GRANTHAM, HERBERT T. Chief Engineer, Belmont Iron Works, 1622 Real Estate Trust Building, Philadelphia, Pa.

1899. GRAVES, EDWIN D. Chief Engineer, Connecticut River Bridge and Highway District, 950 Main Street, Hartford, Conn.

1903. GRAY, JOHN LATHROP. Assistant Superintendent Tidewater Oil Company, East 22d Street, Bayonne, N. J.

ELECTED

1896. GRAY, THOMAS. Professor Dynamic Engineering, Rose Polytechnic Institute, Terra Haute, Ind.

1904. GREEN, MORRIS M. Professor of Mechanical Engineering, Colorado State University, Boulder, Col.

1904. GREENMAN, RUSSELL S. Assistant Engineer, State Engineer's Department, Albany, N. Y.

1902. GREINER, J. E. Engineer of Bridges and Buildings, Baltimore and Ohio Railroad, Mt. Royal Station, Baltimore, Md.

1901. HAGAR, EDWARD M. Manager, Cement Department, Illinois Steel Company, 1060 The Rookery, Chicago, Ill.

1903. HALLETT, NELSON A. Cement Inspector, 1 Ashburton Place, Boston, Mass.

1903. HANCOCK, E. L. Instructor Applied Mechanics, Purdue University, Lafayette, Ind.

1902. HARDING, W. H. President, Bonneville Portland Cement Company, 2029 Land Title Building, Philadelphia, Pa.

1903. HARGROVE, JULIAN O. Assistant Inspector of Asphalt and Cement, 1603 O Street, N. W., Washington, D. C.

1902. HARRIMAN, N. F. Engineer of Tests and Chief Chemist, Union Pacific Railroad, Omaha, Neb.

1903. HARRIS, GEORGE E. Superintendent, Finishing Department, Edgar Thomson Steel Works, Braddock, Pa.

1898. HARTRANFT CEMENT COMPANY, WILLIAM G. Sole Selling Agent for Old Dominion and Phoenix Portland Cement, Real Estate Trust Building, Philadelphia, Pa.

1898. HATT, WILLIAM K. Professor of Applied Mechanics, Purdue University, Lafayette, Ind.

1903. HEARNE, W. W. 1625 Real Estate Trust Building, Philadelphia, Pa.

1904. HEIDENREICH, E. LEE. Consulting Engineer, 721 The Rookery, Chicago, Ill.

1904. HEMSTREET, GEORGE P. Superintendent, Hastings Pavement Company, Hastings-on-Hudson, N. Y.

1903. HENSHAW, JOHN D. Member, F. S. Bartlett and Company, Boston, Mass.

1902. HILDRETH, P. S. Consulting and Inspecting Engineer, 32 Broadway, New York, N. Y.

1903. HILTNER, R. S. Assistant Chemist, Supervising Architect's Office, Treasury Department, Washington, D. C.

1902. HOFMAN, H. O. Professor of Metallurgy, Massachusetts Institute of Technology, Boston, Mass.

ELECTED

1903. HOLMES, JOSEPH A. State Geologist of North Carolina, Chapel Hill, N. C.

1903. HOWARD, L. E. Superintendent, Simonds Manufacturing Company, Seventeenth Street and Western Avenue, Chicago, Ill.

1896. HOWE, HENRY M. (*Past-President*). Professor Metallurgy, Columbia University, 27 West Seventy-third Street, New York, N. Y.

1903. HOY, JOHN F. Chemist, Pennsylvania Car-Wheel Company, Preble Avenue, Allegheny, Pa.

1896. HUMPHREY, RICHARD L. Engineer and General Manager, Buckhorn Portland Cement Company, 1001 Harrison Building, Philadelphia, Pa.

1903. HUNNINGS, S. V. Engineer of Tests, American Locomotive Company, Pittsburg, Pa.

1903. HUNT, LOREN E. Timber Inspecting Expert, U. S. Bureau of Forestry, University of California, Berkeley, Cal.

1899. HUNT, ROBERT W., COMPANY. Inspecting and Testing Engineers, 1121 The Rookery, Chicago, Ill.

1903. HUNTER, JOSEPH W. Engineer and Surveyor, State Highway Commissioner, Harrisburg, Pa.

1899. HUSTON, CHARLES L. Vice-President, Lukens Iron and Steel Company, Coatesville, Pa.

1904. HUTCHINSON, GEORGE W. Engineer of Tests, American Locomotive Company, Richmond Works, Richmond, Va.

1903. HYDE, CHARLES G. Assistant Engineer in Charge of Filters, Board of Public Works, Harrisburg, Pa.

1900. ILLINOIS STEEL COMPANY. P. E. Carhart, Inspecting Engineer, Rookery Building, Chicago, Ill.

1903. INSURANCE ENGINEERING. Franklin Webster, Editor, 120 Liberty Street, New York City, N. Y.

1902. INTERNATIONAL ACHESON GRAPHITE COMPANY. Manufacturers of Graphite and Graphite Articles, Niagara Falls, N. Y.

1902. IRON TRADE REVIEW, THE. A. I. Findley, Editor, Cleveland, O.

1890. JARECKI, ALEXANDER. Superintendent, Jarecki Manufacturing Company, Limited, Erie, Pa.

1897. JENKINS, JOHN. General Manager, Milton Iron Company, Milton, Pa.

1900. JEWETT, J. Y. Cement Inspector, Metropolitan Water Board of Massachusetts, Clinton, Mass.

1900. JOB, ROBERT. Chemist, Philadelphia and Reading Railway, Reading, Pa.

ELECTED

1903. JOHNSON, ALBERT L. Chief Engineer, Expanded Metal Fireproofing Company, 606 Century Building, St. Louis, Mo.

1903. JOHNSON, ARTHUR N. Civil Engineer; Highway Engineer, Maryland Geological Survey, Baltimore, Md.

1903. JOHNSON, CHARLES. Testing Department, American Locomotive Company, Schenectady, N. Y.

1900. JOHNSON, WALLACE C. Consulting Engineer, Niagara Falls, N. Y.

1902. JONES AND LAUGHLINS, LIMITED. Steel Manufacturers; Willis L. King, Vice-Chairman, Pittsburg, Pa.

1903. JORDAN, WILLIAM, JR. Instructor in Civil Engineering, University of Pennsylvania, Philadelphia, Pa.

1903. KEAY, H. O. Chief Draughtsman, Motive Power Department, Boston and Maine Railroad, Boston, Mass.

1896. KEEP, WILLIAM J. Superintendent, Michigan Stove Company, 753 Jefferson Avenue, Detroit, Mich.

1898. KEMP, JAMES F. Professor of Geology, School of Mines, Columbia University, New York, N. Y.

1899. KENNEDY, FRANK G., JR. Superintendent, Logan Iron and Steel Company, Burnham, Mifflin County, Pa.

1899. KENNEDY, JULIAN. Consulting Engineer, Latrobe Company, Pittsburg, Pa.

1902. KENNICOTT, CASS L. General Manager, Kennicott Water Softener Company, 3567 Butler Street, Chicago, Ill.

1902. KENT, WILLIAM. Professor of Mechanical Engineering, and Dean of the L. C. Smith College of Applied Science, Syracuse University, Syracuse, N. Y.

1903. KIESEL, W. F., JR. Assistant Mechanical Engineer, Pennsylvania Railroad, Altoona, Pa.

1899. KING, WILLIS L. Vice-Chairman, Jones and Laughlins, Limited, Pittsburg, Pa.

1899. KINKEAD, J. A. Engineer of Tests, American Locomotive Company, Schenectady, N. Y.

1902. KIRCHHOFF, C. Editor, *The Iron Age*, 232 William Street, New York, N. Y.

1903. KIRCHNER, PAUL A. Bridge Engineer, Chesapeake and Ohio Railway, Richmond, Va.

1903. KITTREDGE, H. G. Secretary, The Kay and Ess Company, Dayton, O.

1903. KNIGHTON, J. A. Assistant Engineer, Bridge Department, Park Row Building, New York, N. Y.

ELECTED

1901. KOEHL, JAMES C. Engineer, 710 North Franklin Street, Kirksville, Adair County, Mo.

1903. KOHR, D. A. Chemist, Lowe Brothers, Dayton, O.

1896. KREUZPOINTNER, PAUL. Pennsylvania Railroad, Altoona, Pa.

1904. KRUPP COMPANY, Fried.; Emil Ehrensberger, Director, Essen, Germany.

1904. KUMMER, FREDERIC A. General Manager, United States Wood Preserving Company, 29 Broadway, New York, N. Y.

1903. LA CHICOTTE, H. A. Engineer in Charge, Manhattan Bridge (No. 3) and Blackwell's Island Bridge (No. 4), Park Row Building, New York, N. Y.

1903. LANE, HENRY M. Editor, *The Foundry*, Rose Building, Cleveland, O.

1899. LANZA, GAETANO. Professor Theoretical and Applied Mechanics, in charge Mechanical Engineering Department, Massachusetts Institute of Technology, Boston, Mass.

1904. LARNED, E. S. Manager, United Building Materials Company, 101 Milk Street, Boston, Mass.

1903. LARSSON, C. G. E. Division Engineer, American Bridge Company, 148 Sumac Street, Philadelphia, Pa.

1898. LATHBURY AND SPACKMAN. Chemical and Physical Laboratories, 1619 Filbert Street, Philadelphia, Pa.

1898. LATROBE STEEL COMPANY. Marriott C. Smyth, President, 1200 Girard Building, Philadelphia, Pa.

1901. LAWRENCE, WILLIAM H. Assistant Professor of Architecture, Massachusetts Institute of Technology, Boston, Mass.

1903. LAYMAN, W. A. General Manager, Wagner Electrical Manufacturing Company, 2017 Locust Street, St. Louis, Mo.

1903. LEMOINE, L. R. Resident Manager, United States Cast-Iron Pipe and Foundry Company, Land Title Building, Philadelphia, Pa.

1898. LESLEY, R. W. (*Vice-President*). President, American Cement Company, 22 South Fifteenth Street, Philadelphia, Pa.

1903. LEWIS, FREDERICK H. Manager, Virginia Portland Cement Company, Craigsville, Va.

1902. LEWIS, GEORGE T. Secretary and Treasurer, Monongahela Iron and Steel Company, Box 215, Pittsburg, Pa.

1904. LEWIS, NELSON P., Chief Engineer, Board of Estimate and Apportionment, City Hall, New York, N. Y.

1896. LINDENTHAL, GUSTAV. Consulting Engineer, 45 Cedar Street, New York, N. Y.

ELECTED

1902. LINTON, HARVEY. City Engineer, Altoona, Pa.

1903. LOBDELL, W. W. President, Lobdell Car-Wheel Company, Wilmington, Del.

1902. LOBER, J. B. Vice-President, Vulcanite Portland Cement Company, Land Title Building, Philadelphia, Pa.

1902. LOCKARD, CHARLES A. Manager, Empire Portland Cement Company, Warners, N. Y.

1904. LOOMIS, HENRY M. Chemist, International Acheson Graphite Company, Box 166, Niagara Falls, N. Y.

1903. LORDLY, HENRY ROBERTSON. Engineer in Charge, Lachine Canal, Royal Insurance Building, Montreal, Canada.

1903. LOUDON, ARCH. M. Foundry Superintendent, Abendroth Bros., Port Chester, N. Y.

1902. LOVELL, EARL B. Adjunct Professor of Civil Engineering, Columbia University, 235 West One Hundred and Second Street, New York, N. Y.

1899. LOWE BROTHERS. Paint and Color Makers; Huston Lowe, Vice-President, Dayton, O.

1900. LOWETH, CHARLES F. Engineer and Superintendent of Bridges and Buildings, Chicago, Milwaukee and St. Paul Railway, 1100 Old Colony Building, Chicago, Ill.

1902. LUKENS IRON AND STEEL COMPANY. Charles L. Huston, Vice-President, Coatesville, Pa.

1898. LUNDTEIGEN, ANDREAS. Chemist, Union City, Mich.

1902. LYNCH, T. D. Inspector of Material, Westinghouse Electrical Manufacturing Company, East Pittsburgh, Pa.

1896. MCCAULEY, H. K. Secretary and Treasurer, Altoona Iron Company, Altoona, Pa.

1903. MCCREADY, ERNEST B. Cement Tester, Rapid Transit Railroad Commission, City of New York, 414 Turner Street, Allentown, Pa,

1902. MCLEOD, JOHN (*Member of Executive Committee*). Assistant to President, Carnegie Steel Company, Pittsburg, Pa.

1903. MCQUEEN, J. W. Secretary, Sloss-Sheffield Iron and Steel Co., Birmingham, Ala.

1902. MCCORMICK DIVISION, INTERNATIONAL HARVESTER COMPANY. F. A. Flather, Superintendent, Blue Island and Western Avenues, Chicago, Ill.

1896. MCKENNA, CHARLES F. Chemist, 221 Pearl Street, New York. N. Y.

ELECTED

1895. MACLAY, WILLIAM W. President, Glens Falls Portland Cement Company, Glens Falls, N. Y.

1902. MACPHERRAN, R. S. Chemist, Allis-Chalmers Company, Milwaukee, Wis.

1902. MAJOR, CHARLES. President, A. and P. Roberts Company; Manager Pencoyd Iron Works, Pencoyd, Pa.

1898. MARBURG, EDGAR (*Secretary-Treasurer*). Professor of Civil Engineering, University of Pennsylvania, Philadelphia, Pa.

1903. MARTIN, HENRY G. Metallurgist, Lukens Iron and Steel Company, P. O. Box 478, Coatesville, Pa.

1902. MARTIN, SIMON S. Superintendent, Steel Department, Maryland Steel Company, Sparrows Point, Md.

1903. MASTERS, J. B. Inspecting Engineer, Pittsburg Representative of Hildreth & Company, 506 North St. Clair Street, Pittsburg, Pa.

1902. MATCHAM, CHARLES A. Manager, Lehigh Portland Cement Company, Allentown, Pa.

1903. MATHEWS, JOHN A. Metallurgist, Experimental Department, Crucible Steel Company of America, Syracuse, N. Y.

1899. MEADE, RICHARD K. Chemist, Northampton Portland Cement Company, Easton, Pa.

1902. MEIER, E. D. President and Chief Engineer, Herne Safety Boiler Company, 11 Broadway, New York, N. Y.

1895. MERRIMAN, MANSFIELD (*Past-President*). Professor of Civil Engineering, Lehigh University, South Bethlehem, Pa.

1903. METCALF, WILLIAM. Braeburn Steel Company, Braeburn, Pa.

1903. MILLER, JOHN S., JR. Assistant Chemist, Supervising Architect's Office, Treasury Department, Washington, D. C.

1903. MILLER, RUDOLPH P. Chief Engineer, Bureau of Buildings, 141 East Fortieth Street, New York, N. Y.

1900. MILLS, CHARLES M. Principal Assistant Engineer, Subway and Elevated Railroad Construction, Rapid Transit Company, Philadelphia, Pa.

1903. MITCHELL, ARTHUR M. Secretary, The Eureka Chemical Company, 5 Howard Street, Newark, N. J.

1903. MITCHELL, JOSEPH. With John Williams Bronze and Iron Works, 556 West 27th Street, New York City, N. Y.

1901. MITCHELL, WILLIAM H. 519 Arch Street, Philadelphia, Pa.

1903. MOISSEFF, LEON S. Assistant Engineer to Commissioner of Bridges, 13 Park Row, New York City, N. Y.

1896. MOLDENKE, RICHARD G. Metallurgist, Consulting Engineer, Box 432, New York, N. Y.

ELECTED

1903. MOORE, HERBERT F. Mechanical Engineer, Riehlé Bros. Testing Machine Company, 1424 North Ninth Street, Philadelphia, Pa.

1902. MOORE, WILLIAM HARLEY. Engineer of Bridges, New York, New Haven and Hartford Railroad, New Haven, Conn.

1904. MOSELEY, ALEX. W. Assistant Professor of Applied Mechanics, Lewis Institute, Chicago, Ill.

1899. MUESER, WILLIAM. Civil Engineer; Member, Concrete Steel Engineering Company, 13–21 Park Row Building, New York, N. Y.

1903. MUNROE, CHARLES E. Columbian University, Washington, D. C.

1899. MUTUAL BOILER INSURANCE COMPANY. 31 Milk Street, Boston, Mass.

1900. NATIONAL TUBE COMPANY. Taylor Allderdice, Assistant to First Vice-President, Conestoga Building, Pittsburg, Pa.

1896. NEALE, JAMES. Secretary, Wayne Iron Works, Pittsburg, Pa.

1902. NEFF, F. H. Professor of Civil Engineering, Case School of Applied Science, Cleveland, O.

1902. NEW YORK AIR BRAKE COMPANY, THE. R. C. Augur, Mechanical Engineer, Watertown, N. Y.

1898. NEWBERRY, SPENCER B. Manager, Sandusky Portland Cement Company, Sandusky, O.

1903. NEWCOMER, H. C. Captain, Corps of Engineers, U. S. Army, Washington Barracks, Washington, D. C.

1903. NOBLE, ALFRED. Chief Engineer, East River Section, Pennsylvania, New York and Long Island Railroad, 20 West Thirty-fourth Street, New York, N. Y.

1902. NORRIS, GEORGE L. Chemist, Standard Steel Works, Burnham, Pa.

1903. NORTON, C. L. Assistant Professor of Heat Measurement, Massachusetts Institute of Technology, Boston, Mass.

1898. OLSEN, TINIUS. Tinius Olsen and Company, Testing Machines, 500 North Twelfth Street, Philadelphia, Pa.

1902. ONDERDONK, J. R. Engineer of Tests, Baltimore and Ohio Railroad, Mt. Clare, Baltimore, Md.

1903. ORFORD COPPER COMPANY. 43 Exchange Place, New York, N. Y.

1902. ORTON, EDWARD, JR. Dean, College of Engineering, Ohio State University, and State Geologist of Ohio, Columbus, O.

ELECTED

1898. OSBORN ENGINEERING COMPANY, THE. Frank C. Osborn, Cleveland, Ohio.

1903. OSTROM, JOHN N. Bridge Engineer, 1518 Farmers' Bank Building, Pittsburg, Pa.

1902. OUTERBRIDGE, ALEX. E., JR. Chemist and Metallurgist, 1600 Hamilton Street, Philadelphia, Pa.

1903. PAGE, LOGAN WALLER. Chief of Road Material Laboratory, United States Department of Agriculture, Washington, D. C.

1903. PARK, LOUIS L. Chief Draughtsman, Rogers Locomotive Works, Paterson, N. J.

1902. PATTERSON-SARGENT COMPANY. Benjamin Patterson, President, Cleveland, O.

1903. PEABODY, CHARLES H. Professor, Massachusetts Institute of Technology, Boston, Mass.

1902. PEARSON, H. C. Editor, *India Rubber World*, 150 Nassau Street, New York, N. Y.

1896. PEASE, F. N. Assistant Chemist, Pennsylvania Railroad, Altoona, Pa.

1903. PECKHAM, S. F. Chemist to the Commissioners of Accounts, New York City, Room 104, 280 Broadway, New York, N. Y.

1903. PECKITT, LEONARD. President, Empire Steel and Iron Company, Catasauqua, Pa.

1902. PENNSYLVANIA STEEL COMPANY, THE. H. H. Campbell, Superintendent and General Manager, Steelton, Pa.

1903. PHILLIPS, WILLIAM BATTLE. Mining Engineer and Metallurgist; Director, University of Texas Mineral Survey, Austin, Tex.

1903. PINCHOT, GIFFORD. Forester, United States Department of Agriculture, Washington, D. C.

1902. POLK, W. A. Sales Agent, The Patterson-Sargent Company, 42 Hudson Street, New York, N. Y.

1898. PORTER, JAMES MADISON. Professor of Civil Engineering, Lafayette College, Easton, Pa.

1903. POWELL, H. S. Sanitary Engineer, 149 Broadway, New York, N. Y.

1904. POWELL, J. E. Chief Mechanical and Electrical Engineer, Office of Supervising Architect, Treasury Department, Washington, D. C.

1903. POWERS, W. A. Chief Chemist, Atchison, Topeka and Santa Fé Railroad, Topeka, Kan.

1903. PRICE, MORTON MOORE. Civil Engineer, Babcock and Wilcox Company, Bayonne, N. J.

ELECTED

1903. QUIMBY, H. H. Assistant Engineer of Bridges, Bureau of Surveys, 863 North Twenty-third Street, Philadelphia, Pa.

1898. RAILROAD GAZETTE. W. H. Boardman, Editor, 83 Fulton Street, New York, N. Y.

1902. RAILWAY AND ENGINEERING REVIEW. W. M. Camp, Editor, 1305 Manhattan Building, Chicago, Ill.

1904. RAMAGE, J. C. Superintendent of Tests, Southern Railway Company, Alexandria, Va.

1896. RANDOLPH, LINGAN S. Professor of Mechanical Engineering, Virginia Polytechnic Institute, Blacksburg, Va.

1902. READING IRON COMPANY. David Thomas, Superintendent, Montaur Rolling Mills, Danville, Pa.

1902. REID, DAVID. Superintendent of Rarig Engineering Company, 239 Taylor Avenue, Columbus, Ohio.

1903. REYNDERS, J. V. W. Superintendent, Bridge and Construction Department, Pennsylvania Steel Company, Steelton, Pa.

1898. RICE, FRANCIS S. Structural Engineer, Aspinwall, Pa.

1900. RICHARDS, JOSEPH T. Engineer, Maintenance of Way, Pennsylvania Railroad, Broad Street Station, Philadelphia, Pa.

1902. RICHARDS, JOSEPH W. Assistant Professor of Metallurgy, Lehigh University, Bethlehem, Pa.

1902. RICHARDS, ROBERT H. Professor of Mining Engineering and Metallurgy, Massachusetts Institute of Technology, Boston, Mass.

1896. RICHARDSON, CLIFFORD. Asphalt Expert, New York Testing Laboratory, Long Island City, N. Y.

1903. RICHARDSON, WILLARD D. Ceramic Engineer, Columbus, O.

1900. RICHTER, A. W. Assistant Professor of Experimental Engineering, 428 Murray Street, Madison, Wis.

1902. RIEGNER, W. B. Engineer of Bridges, Philadelphia and Reading Railway, Reading Terminal, Philadelphia.

1898. RIEHLE, FREDERICK A. Riehlé Brothers Testing Machine Company, 1424 North Ninth Street, Philadelphia, Pa.

1904. ROBERTS, ALFRED E. Analytical and Consulting Chemist and Metallurgist, Bull & Roberts, 100 Maiden Lane, New York, N. Y.

1904. ROBINSON, A. F. Bridge Engineer, Atchison, Topeka and Santa Fé Railroad, Topeka, Kan.

1903. ROBINSON, JOHN C. Secretary and Treasurer, St. Louis Portland Cement Company, St. Louis, Mo.

1900. ROEBLING'S (JOHN A.) SONS COMPANY. J. H. Janeway, Jr., Mechanical Engineer, Trenton, N. J.

ELECTED

1903. ROTH, FILIBERT. Professor of Forestry, University of Michigan, Ann Arbor, Mich.

1903. ROYAL, JOSEPH. Inspecting Engineer, P. O. Box 174, Rutledge, Pa.

1898. SABIN, A. H. Chemist, 45 Broadway, New York, N. Y.

1902. SABIN, L. C. United States Assistant Engineer, Engineer Department, U. S. Army, Sault Ste. Marie, Mich.

1902. SAGUE, J. E. Mechanical Engineer, American Locomotive Company, 25 Broad Street, New York, N. Y.

1903. SARGENT, GEORGE W. Chemist, Carpenter Steel Company, Reading, Pa.

1902. SAUNDERS, WALTER M. Analytical and Consulting Chemist, 184 Whittier Avenue, Providence, R. I.

1896. SAUVEUR, ALBERT. Assistant Professor of Metallurgy, Harvard University; Manager, Boston Testing Laboratories, 446 Tremont Street, Boston, Mass.

1903. SCARBOROUGH, F. W. Engineer, Maintenance of Way, Chesapeake and Ohio Railway, 302 West Franklin Street, Richmond, Va.

1898. SCHAFFER, HERBERT A. Chief Chemist, The Northampton and Quaker Portland Cement Company, 321 Spring Garden Street, Easton, Pa.

1900. SCHNEIDER, HERMAN. Instructor in Civil Engineering, Lehigh University, South Bethlehem, Pa.

1903. SCHROEDER, C. M. Chemist, 221 Pearl Street, New York, N.Y.

1902. SCHUERMAN, W. H. Dean of Engineering Department and Professor of Civil Engineering, Vanderbilt University, Nashville, Tenn.

1898. SCHUMANN, FRANCIS. Civil and Mechanical Engineer, 7000 Tulip Street, Tacony, Philadelphia, Pa.

1904. SCOTT, WILLIAM F. Structural Engineer, with John G. Howard, Architect, Berkeley, Cal.

1902. SCOTT, W. G. Chemist, J. I. Case Threshing Machine Company, 1109 Park Avenue, Racine, Wis.

1898. SEAMAN, HARRY J. Superintendent, Atlas Cement Company, Catasauqua, Pa.

1902. SEAMAN, HENRY B. Civil Engineer, 40 Wall Street, New York, N. Y.

1904. SELLERS AND COMPANY, WILLIAM. William Sellers, President, 1600 Hamilton Street, Philadelphia, Pa.

1902. SHANKLAND, E. C. AND R. M. Civil Engineers 1106 Rookery, Chicago, Ill.

ELECTED

1903. SHLAFF, J. C. Manager, Patterson Sargent Company, 42 Hudson Street, New York, N. Y.

1902. SHELBY STEEL TUBE COMPANY. J. H. Nicholson, Assistant to First Vice-President, The Frick Building, Pittsburg, Pa.

1903. SHERMAN, C. W. General Manager, Pennsylvania Malleable Company, Central Car Wheel Company, Frick Building, Pittsburg, Pa.

1903. SHERRERD, MORRIS R. Engineer and Superintendent, Department of Water, City of Newark, 128 Halsey Street, Newark, N. J.

1902. SHERWIN WILLIAMS COMPANY, THE. Paint and Varnish Makers. E. C. Holton, Chemist in Chief, 100 Canal Street, Cleveland, O.

1899. SHIMER, PORTER W. Chemist and Metallurgist, Easton, Pa.

1902. SHUMAN, JESSE J. Chief Inspector, Testing Department, Jones and Laughlin Steel Company, 837 Heberton Avenue, Pittsburg, Pa.

1903. SKINNER, C. E. Electrical Engineer, Westinghouse Electric Manufacturing Company, East Pittsburg, Pa.

1903. SLOCUM, A. W. General Superintendent, Keystone Car Wheel Company, Pittsburg, Pa.

1902. SMITH, H. E. Chemist, The Lake Shore and Michigan Southern Railway Company, Collinwood, O.

1902. SNOW, J. P. Bridge Engineer, Boston and Maine Railroad, Boston, Mass. *For Mail*, 58 Chandler Street, West Somerville, Mass.

1904. SOULE, R. H. Consulting Engineer, 20 West Thirty-fourth Street, New York, N. Y.

1903. SOUTHER, HENRY. Consulting Metallurgical Engineer, State Chemist, 440 Capitol Avenue, Hartford, Conn.

1902. SPANGLER, H. W. Professor of Mechanical Engineering, University of Pennsylvania, Philadelphia, Pa.

1901. SPERRY, W. L. Superintendent and Manager, The Cumberland Hydraulic Cement and Manufacturing Company, P. O. Box 234, Cumberland, Md.

1902. STANDARD STEEL WORKS. A. A. Stevenson, Assistant Superintendent, Burnham, Pa.

1903. STAPLETON, F. M. Inspector, Chicago and Northwestern Railway, 504 Smithfield Street, Pittsburg, Pa.

1896. STAUFFER, DAVID McN. Civil Engineer; Editor, *Engineering News*, 220 Broadway, New York, N. Y.

1899. STEINMAN, A. J. Chairman, Pennsylvania Iron Company, Limited, Lancaster, Pa.

ELECTED

1890. STEVENSON, A. A. Assistant Superintendent, Standard Steel Works, Burnham, Mifflin County, Pa.

1903. STEWART, CLINTON R. Engineer of Tests, Cambria Steel Company, Johnstown, Pa.

1899. STILLMAN, THOMAS B. Professor of Chemistry, Stevens Institute of Technology, Hoboken, N. J.

1903. STOREY, W. B., JR. Chief Engineer, Atchison, Topeka and Santa Fé Railroad Company, 528 Crossley Building, San Francisco, Cal.

1902. STOUGHTON, BRADLEY. Tutor in Metallurgy, and Consulting Metallurgist, Columbia University, New York, N. Y.

1903. STRATTON, E. PLATT. Chief Engineer Surveyor, American Bureau of Shipping, 66–70 Beaver Street, New York, N. Y.

1903. STREETER, LAFAYETTE P. Engineer of Tests, New York Air-Brake Company, Box 363, Watertown, N. Y.

1896. STROBEL, CHARLES L. Consulting Engineer, 1744 Monadnock Block, Chicago, Ill.

1903. SULLIVAN, THOMAS V. Chemist, 417 West One Hundred and Seventeenth Street, New York, N. Y.

1896. SWAIN, GEORGE F. Professor of Civil Engineering, Massachusetts Institute of Technology, Boston, Mass.

1903. SWANBERG, F. L. Mechanical Engineer, The Lukenheimer Company, Cincinnati, O.

1903. SWENSSON, EMIL. Consulting Engineer, Frick Building, Pittsburg, Pa.

1903. TAGGART, HOWARD. Engineer of Tests, Lukens Iron and Steel Company, P. O. Box 632, Coatesville, Pa.

1898. TALBOT, ARTHUR N. Professor of Municipal and Sanitary Engineering, University of Illinois, Urbana, Ill.

1902. TALBOT, HENRY P. Professor of Inorganic and Analytical Chemistry, Massachusetts Institute of Technology, Boston, Mass.

1900. TAYLOR, WILLIAM PURVES. Engineer in Charge, Testing Laboratory, 418 City Hall, Philadelphia, Pa.

1896. TECHNISCHER VEREIN, BROOKLYN. W. Schad, Secretary, 105 North Eleventh Street, Brooklyn, N. Y.

1896. TECHNISCHER VEREIN, NEW YORK. Carl Kaelble, Secretary, Room 705, 290 Broadway, New York, N. Y.

1896. TECHNISCHER VEREIN, PHILADELPHIA. 534 North Fourth Street, Philadelphia, Pa.

1896. TECHNISCHER VEREIN, PITTSBURG. E. F. Harder, Secretary, 321 Savannah Avenue, Pittsburg, Pa.

ELECTED

1896. TECHNISCHER VEREIN, WASHINGTON. Paul Bausch, Corresponding Secretary, 3418 Brown Street, N. W., Washington, D. C.

1902. THACHER, EDWIN. Consulting Engineer; Member, Concrete-Steel Engineering Company, Park Row Building, New York, N. Y.

1900. THOMAS, DAVID. Assistant to President, Reading Iron Company, Reading, Pa.

1903. THOMPSON, GUSTAVE W. Chemist, National Lead Company, 129 York Street, Brooklyn, N. Y.

1900. TIPPETT AND WOOD. Plate Iron and Steel Workers, Phillipsburg, N. J.

1903. TOCH, MAXIMILIAN. Paint Manufacturer, 468 West Broadway, New York, N. Y.

1903. TOMKINS, CALVIN. Manufacturer, 17 Battery Place, New York, N. Y.

1903. TOUCEDA, ENRIQUE. Chemist and Metallurgist, 51 State Street, Albany, N. Y.

1902. TURNEAURE, F. E. Professor of Bridge and Sanitary Engineering, University of Wisconsin, Madison, Wis.

1902. UMSTEAD, C. H. Superintendent of Construction, U. S. Public Buildings, 39 Blakeley Building, Lawrence, Mass.

1903. VAN GUNDY, C. P. Chief Chemist, Baltimore and Ohio Railroad, Mont Clare, Baltimore, Md.

1902. VAN ORNUM, J. L. Professor of Civil Engineering, Washington University, St. Louis, Mo.

1903. VANNIER, CHARLES H. Griffin Wheel Company, Sacramento Square, Chicago, Ill.

1896. VOGT, A. S. Mechanical Engineer, Pennsylvania Railroad, Altoona, Pa.

1903. VON SCHRENK, HERMANN. Investigator, Chief Division of Forest Products, Bureau of Forestry, U. S. Department of Agriculture, Washington, D. C.

1902. VOORHEES, S. S. Engineer of Tests, Treasury Department, Washington, D. C.

1903. VREDENBURGH, WATSON, JR. Professor of Civil Engineering, Manhattan College, 50 Broadway, New York, N. Y.

1896. WADDELL, J. A. L. Consulting Civil Engineer, Kansas City, Mo.

1899. WAGNER, SAMUEL TOBIAS. Assistant Engineer, Philadelphia and Reading Railway, Reading Terminal, Philadelphia, Pa.

ELECTED

1903. WAID, D. EVERETT. Architect, 156 Fifth Avenue, New York, N.Y.

1902. WALKER, JOSEPH F. Chemist, The Protectus Company, Bridgeport, Pa.

1903. WALKER, R. F. Cement Tester in Charge, Rapid Transit Railway, New York, 412 Turner Street, Allentown, Pa.

1903. WALKER, W. H. Associate Professor of Industrial Chemistry, Massachusetts Institute of Technology, of the firm, Little and Walker, Chemical Experts and Engineers, 93 Broad Street, Boston, Mass.

1903. WALSH, W. F. Sales Agent, Fuller Brothers and Company, 139 Greenwich Street, New York, N. Y.

1903. WALTER, LEE W. Cement Inspector, Baltimore and Ohio Railroad, B. and O. Cement Laboratory, Wheeling, W. Va.

1903. WARNER, GEORGE C. Sullivan Machinery Company, P. O. Box 33, Claremont, N. H.

1900. WEBSTER, GEORGE S. Chief Engineer and Surveyor, Bureau of Surveys, 418 City Hall, Philadelphia, Pa.

1898. WEBSTER, WILLIAM R. Civil Engineer, 411 Walnut Street, Philadelphia, Pa.

1903. WEMLINGER, J. R. Engineer, Cambria Steel Company, Westmont, Johnstown, Pa.

1897. WEST, THOMAS D. Foundry Expert, Sharpsville, Pa.

1900. WHITEHEAD, J. W., JR. Joseph Dixon Crucible Company, Jersey City, N. J.

1903. WHITING, JASPER. Metallurgical Engineer, 53 State Street, Boston, Mass.

1902. WHITNEY, ASA W. Foundry Specialist, Sanford-Day Iron Works, Knoxville, Tenn.

1902. WHITNEY, WILLIS R. Associate Professor of Chemistry, Massachusetts Institute of Technology, Boston, Mass.

1898. WICKHORST, MAX H. Engineer of Tests, Chicago, Burlington and Quincy Railroad, Aurora, Ill.

1902. WILHELM COMPANY, THE A. Paint Makers, Reading, Pa.

1903. WILKINS, A. D. Chemist, Box 34, Elizabeth, Pa.

1898. WILLE, H. V. Engineer of Tests, Baldwin Locomotive Works, 500 North Broad Street, Philadelphia, Pa.

1900. WING, CHARLES B. Professor of Structural Engineering, Stanford University, Cal.

1903. WITTMAN, N. B. Potts and Wittman, North American Building, Philadelphia, Pa.

1903. WOLFEL, PAUL L. Chief Engineer, American Bridge Company, Ambridge, Pa.

ELECTED

1902. WOOD AND COMPANY, R. D., Founders. Walter Wood, 400 Chestnut Street, Philadelphia, Pa.

1903. WOOD, ALAN D. Superintendent, Alan Wood Iron and Steel Company, Conshohocken, Pa.

1903. WOOD, EDWARD R., JR. Manufacturer, 400 Chestnut Street, Philadelphia, Pa.

1903. WOOD, F. W. President, Maryland Steel Company, Sparrows Point, Md.

1900. WOOD, WALTER. Cast-Iron Pipe Manufacturer, R. D. Wood Company, 400 Chestnut Street, Philadelphia, Pa.

1903. WOODMAN, DURAND. Analytical and Technical Chemist, 80 Beaver Street, New York, N. Y.

1900. WOOLSON, IRA H. Adjunct Professor of Mechanical Engineering, Columbia University, New York, N. Y.

1904. WORCESTER, JOSEPH R. Consulting Engineer, 53 State Street, Boston, Mass.

1903. WORTHINGTON, CHARLES. Consulting Engineer, 1322 Farmers' Bank Building, Pittsburg, Pa.

1902. WYCKOFF, CHARLES, JR. Instructor in College of Civil Engineering, Cornell University, and 185 Penn Street, Brooklyn. N. Y

1903. ZEHNDER, C. H. Manager, Rogers, Brown & Warren, Pennsylvania Building, Philadelphia, Pa.

GEOGRAPHICAL DISTRIBUTION OF MEMBERS.

Alabama	2	Maryland	8	Rhode Island	3
California	6	Massachusetts	26	Tennessee	1
Colorado	4	Michigan	5	Texas	1
Connecticut	6	Missouri	7	Virginia	8
Delaware	1	Nebraska	1	Washington	1
Dist. of Columbia	13	New Hampshire	2	West Virginia	2
Illinois	28	New Jersey	16	Wisconsin	4
Indiana	6	New York	97	Canada	5
Iowa	1	North Carolina	1	Cuba	1
Kansas	2	Ohio	16	Germany	2
Kentucky	1	Pennsylvania	152	Total	429

DECEASED MEMBERS.

Name.	Date of Membership.	Date of Death.
W. P. Black	1896	December 12, 1902.
Henry U. Frankel	1903	December 8, 1903.
Charles Jarecki	1896	January 26, 1901.
J. B. Johnson	1899	June 23, 1902.
G. M. McCauley	1898	May 25, 1901.
George S. Morison	1896	July 1, 1903.
Henry Morton	1896	May 9, 1902.
Robert H. Thurston	1896	October 25, 1903.

PAST OFFICERS.

NOTE.—The Society, from its organization in 1898 till its incorporation under its present name in 1902, was designated The American Section of the International Association for Testing Materials.

The officers and members of the Executive Committee during this four-year period were as follows:

CHAIRMEN.

MANSFIELD MERRIMAN, 1898-1900.
HENRY M. HOWE, 1900-1902.

VICE-CHAIRMEN.

HENRY M. HOWE, 1898-1900.
CHARLES B. DUDLEY, 1900-1902.

SECRETARIES.

RICHARD L. HUMPHREY, 1898-1900.
J. M. PORTER, 1900-1902.

TREASURERS.

PAUL KREUZPOINTNER, 1898-1900.
R. W. LESLEY, 1900-1902.

MEMBERS OF EXECUTIVE COMMITTEE.

GUS. C. HENNING, 1898-1900.
ALBERT LADD COLBY, 1900-1902.

TECHNICAL COMMITTEES

OF THE

AMERICAN SOCIETY FOR TESTING MATERIALS.

Committee A. on Standard Specifications for Iron and Steel.

William R. Webster, *Chairman.*
Edgar Marburg, *Secretary.*

American Steel and Wire Company,
  F. H. Daniels.
Bethlehem Steel Company,
  E. O'C. Acker.
Cambria Steel Company,
  George E. Thackray.
Carnegie Steel Company,
  John McLeod.
Central Iron and Steel Company,
  James B. Bailey.
Charles S. Churchill.
James Christie.
J. Allen Colby.
Colorado Fuel and Iron Company,
  C. S. Robinson.
John Sterling Deans.
P. H. Dudley.
Franklin Institute,
  Alex. E. Outerbridge, Jr.
Robert W. Hunt Company.
Illinois Steel Company,
  P. E. Carhart.
Jones and Laughlins, Limited,
  Willis L. King.
Gaetano Lauza.
Lukens Iron and Steel Company,
  Charles L. Houston.
Edgar Marburg.
Richard G. G. Moldenke.
National Tube Company,
  Taylor Allderslice.
The Osborn Engineering Company,
  Frank C. Osborn.
The Pennsylvania Steel Company,
  H. H. Campbell.
Reading Iron Company,
  David Thomas.
Joseph T. Richards.
John A. Roebling's Sons Company,
  J. H. Janeway.
Shelby Steel Tube Company,
  J. H. Nicholson.
Standard Steel Works,
  A. A. Stevenson.
J. A. L. Waddell.
Samuel T. Wagner.
William R. Webster.
Max H. Wickhorst.
H. V. Wille.
R. D. Wood and Company,
  Walter Wood.

Committee B. on Standard Specifications for Cast Iron and Finished Castings.

Walter Wood, *Chairman.*
Richard G. Moldenke, *Secretary.*

Hugh W. Adams.
James A. Beckett.
Robert Bentley.
Joseph W. Bramwell.
H. H. Campbell.
Colorado Fuel and Iron Company,
  C. S. Robinson.
Albert Ladd Colby.

COMMITTEE B.—*Continued.*

Edgar S. Cook.
H. A. Croxton.
George M. Davidson.
H. E. Diller.
J. K. Dimmick.
W. C. Du Comb.
Charles B. Dudley.
George F. Eldridge.
L. M. Fenner.
H. E. Field.
A. D. Findley.
Stanley G. Flagg, Jr.
William Gerhauser.
W. K. Hatt.
W. H. Hearne.
John D. Henshaw.
P. S. Hildreth.
Henry M. Howe.
Illinois Steel Company,
P. E. Carhart.
R. Job.
Jones and Laughlins, Limited,
Willis L. King.
W. J. Keep.
J. F. Kinkead.
P. Kreuzpointner.
G. Lanza.
L. R. Lemoine.
William W. Lobdell.
A. E. Loudon.
McCormick Division, International Harvester Company,
F. A. Flather.
Chales F. McKenna.
J. W. McQueen.
R. S. MacPherran.
Mansfield Merriman.
Richard G. Moldenke.
Tinius Olsen.
Alex. E. Outerbridge, Jr.
Leonard Peckitt.
L. S. Randolph.
David Reid.
Walter M. Saunders.
Albert Sauveur.
W. G. Scott.
C. W. Sherman.
A. W. Slocum.
Henry Souther.
H. W. Spangler.
Technischer Verein, Brooklyn,
B. Viola.
Technischer Verein, Pittsburg,
S. H. Stupakoff.
Enrique Touceda.
C. H Vannier.
W. R. Webster.
Thomas D. West.
Asa W. Whitney.
H. V. Wille.
N. B. Wittman.
F. W. Wood.
E. R. Wood, Jr.
Walter Wood.
I. H. Woolson.
C. H. Zehnder.

COMMITTEE C, ON STANDARD SPECIFICATIONS FOR CEMENT.

GEORGE F. SWAIN, *Chairman.*
GEORGE S. WEBSTER, *Vice-Chairman.*
RICHARD L. HUMPHREY, *Secretary.*

Booth, Garrett & Blair.
C. W. Boynton.
T. J. Brady.
Spencer Cosby.
A. W. Dow.
L. Henry Dumary.
A. F. Gerstell.
Edward M. Hagar.
W. H. Harding.
Richard L. Humphrey.
Lathbury and Spackman.
Robert W. Lesley.
F. H. Lewis.
John B. Lober.
Andreas Lundteigen.
Charles F. McKenna.
W. W. Maclay.
Charles A. Matcham.
Spencer B. Newberry.
Alfred Noble.
James Madison Porter.
Joseph T. Richards.
Clifford Richardson.
L. C. Sabin.
Harry J. Seaman.
George F. Swain.
S. S. Voorhees.
George S. Webster.

COMMITTEE D, ON STANDARD SPECIFICATIONS FOR PAVING AND BUILDING BRICK.

EDWARD ORTON, JR., *Chairman.*

Ira O. Baker.
W. K. Hatt.
Edgar Marburg.
Edward Orton, Jr.
Logan Waller Page.
W. D. Richardson.
Arthur N. Talbot.

COMMITTEE E, ON PRESERVATIVE COATINGS FOR IRON AND STEEL.

S. S. VOORHEES, *Chairman.*
JOSEPH F. WALKER, *Secretary.*

W. A. Aiken.
The Joseph Dixon Crucible Company,
Malcolm MacNaughton.
Charles B. Dudley.
N. F. Harriman.
International Acheson Graphite Co.,
C. L. Collins.
Robert Job.
Spencer B. Newberry.
Charles L. Norton.
Patterson-Sargent Company,
W. A. Polk.
W. A. Powers.
A. H. Sabin.
G. W. Thomson.
S. S. Voorhees.
Joseph F. Walker.
J. W. Whitehead, Jr.
Max H. Wickhorst.
The A. Wilhelm Company,
Charles J. Davies.
William R. Webster.

COMMITTEE F, ON HEAT TREATMENT OF IRON AND STEEL.

Henry M. Howe.
Albert Sauveur.

COMMITTEE G, ON THE MAGNETIC TESTING OF IRON AND STEEL.

J. WALTER ESTERLINE, *Chairman.*

John A. Capp.
J. Walter Esterline.
W. A. Layman.
Richard G. Moldenke.
J. A. Mathews.

COMMITTEE H, ON STANDARD TESTS FOR ROAD MATERIALS.

LOGAN WALLER PAGE, *Chairman.*
ARTHUR N. JOHNSON, *Secretary.*

Ira O. Baker.
Henry I. Budd.
A. W. Dow.
A. B. Fletcher.
G. B. Hemstreet.
J. A. Holmes.
Arthur N. Johnson.
Frederic A. Kummer.
Nelson P. Lewis.
Henry C. Newcomer.
Logan Waller Page.
Calvin Tomkins.

COMMITTEE I, ON STEEL-CONCRETE.

R. W. LESLEY, *Chairman pro tem.*

E. Lee Heidenreich.
R. L. Humphrey.
A. L. Johnson.
R. W. Lesley.
Edgar Marburg.
C. M. Mills.
L. S. Moisseff.
H. H. Quimby.
W. P. Taylor.
F. E. Turneaure.

COMMITTEE J, ON CORROSION OF METALS.

(In course of organization.)

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE.

Since the Fifth Annual Meeting of the Society, the Executive Committee has held five meetings, of which one was informal by reason of the absence of a quorum. An abstract of the minutes of these meetings is appended to this report.

The Society's record during the past year is highly gratifying. The membership has doubled, or, to be exact, has risen from 175 to 349. The new plan of publication in the form of annual volumes instead of bulletins issued at irregular intervals has met with general approval. The first volume thus issued during the past year contains 388 pages, as against an average output of 67 pages per annum during the preceding four years of the Society's existence. The Proceedings have been widely and most favorably noticed in the technical press. The program of the Sixth Annual Meeting promises equally good or even better results for the coming year.

Committees.—Much of the most valuable work of the Society must necessarily be done through its committees. Of the older committees some have been discharged, others reorganized and strengthened, and several new committees have been created. The complete list of existing committees is as follows:

A. On Standard Specifications for Iron and Steel

B. On Standard Specifications for Cast Iron and Finished Castings.

C. On Standard Specifications for Cement.

D. On Standard Specifications for Paving and Building Brick.

E. On Preservative Coatings for Iron and Steel.

F. On Heat Treatment of Iron and Steel.

G. On the Magnetic Properties of Iron and Steel.

H. On Bitumen.

With one or two exceptions, all of these committees are expected to present reports for the year at this meeting.

Publications.—In addition to the annual volume, designated Volume II. of the Proceedings, two pamphlets of 53 and 69 pages respectively, containing the list of members and other information concerning the Society, have been issued. Announcements of

minor, or temporary, interest have been made from time to time through a series of numbered circulars, of which six have appeared during the year.

Membership.—The total membership at the last Annual Meeting was 175. During the year 181 new applications to membership have been received and accepted. There has been a loss of five members by resignation, and of two by death: J. B. Johnson died on June 23, 1902, and W. P. Black on December 12, 1902. The net increase in the membership is 174 for the year, making a total at present of 349. Of this number 11 are in arrears for their dues for more than the current year, viz.: 1 for 5 years, 2 for 4 years, 4 for 3 years, and 4 for 2 years. The new By-Laws empowering the Executive Committee to strike the names of delinquents from the roll of membership has now been in force one year, and the committee proposes to exercise this authority at its next quarterly meeting.

Relations with the International Association for Testing Materials.—Close relations have been maintained with the International Association throughout the year by frequent correspondence. The only printed matter furnished to our members during the past year at the expense of the International Association consists of the English translation of the Revised By-Laws of the Association, the Revised List of International Committees, etc., the Minutes of the Buda-Pesth Congress and of the Tenth Annual Meeting of the Council. The translations of these minutes were both prepared under the supervision of our Society in view of the numerous complaints received in the past by reason of the faulty rendition of the original text into English. The President has given the assurance that every effort will be made to improve translations in the future. The Minutes of the Eleventh Annual Meeting of the International Council, held in Vienna, March 9–10, 1903, are promised for early delivery. From an advance copy recently received, it appears that national societies similar to our own exist now in Germany, France, Italy, Hungary and Norway, and that the total membership in the Association is 1937. The next Congress will be held in St. Petersburg, August 18–24, 1904. All material to be presented at that Congress must be in the hands of President Tetmajer by January 15, 1904, in order that the same may be translated, printed and distributed well in advance of the convention. The question of translating all papers into English, with a view of their free distribution among the English-speaking members, is still undecided. The

Executive Committee proposes to introduce a resolution at this meeting urging the International Council to take measures to that end.

Finances.—The financial condition of the Society appears from the following report for the year on the part of the Treasurer:

ANNUAL REPORT OF THE TREASURER.

From June 9, 1902, to June 30, 1903.

RECEIPTS.

Membership dues	$1174 00	
Excess remittances	16	
Subscriptions	2550 00	
Sales of publications	54 05	
Reprints	98 69	
Orders for binding	60 75	
Interest on deposits	15 18	
Total receipts	$3952 83	
Cash balance, June 9, 1902	87 51	
		$4040 34

DISBURSEMENTS.

Membership dues, International Association	$ 552 00	
Subscription to the International Association	20 00	
Printing, engraving, binding, stationery, etc	1766 47	
Secretary's salary	800 00	
Clerical services	200 00	
Expenses Secretary's office	142 44	
Stenographer, Fifth Annual Meeting	156 36	
Charter	89 00	
Committees' expenses	25 80	
Translating	25 00	
Total disbursements	$3777 07	
Cash balance, July 1, 1903	263 27	
		$4040 34

There are no unpaid bills on hand, July 1, 1903, and the known liabilities aggregate about $125. The financial question is a serious one, to which the Executive Committee has given much thought. The operations of the year could not have been carried to a successful issue without generous subscriptions. During the past year these have aggregated $2550. At the present rate of growth the Society should become self-sustaining within a few years with a moderate increase of dues. In the

mean time the Executive Committee recommends the creation of a new class of members to be known as "Contributing Members." The proposed change in the By-Laws to render this measure effective has been duly announced in circular No. 5 and will be submitted at this meeting for formal action. It is recommended that Section 3, Article I., be designated Section 4, and that a new Section 3 be inserted, viz.: "Any member who subscribes annually the sum of fifty dollars ($50) toward the general funds of the Society shall be designated a Contributing Member, his rights and privileges as a member remaining unchanged." It is believed that the services rendered by the Society to manufacturers and consumers alike in affording them a medium for the free interchange of views on common ground is fully appreciated and that financial support in the form proposed will be readily forthcoming.

Submitted on behalf of the Executive Committee,

EDGAR MARBURG,
Secretary.

CHARLES B. DUDLEY,
President.

REPORT OF AUDITING COMMITTEE.

PHILADELPHIA, PA., July 1, 1903.

To the Executive Committee of the American Society for Testing Materials:

We have examined the books and accounts of the Secretary and Treasurer, from January 1, 1903—the date of the last audit—to July 1, 1903, the date of the annual report of the Treasurer, and find the cash balance of $263.27 to be correct.

[Signed]

JAMES CHRISTIE,
R. W. LESLEY,
Auditing Committee.

APPENDIX.

ABSTRACT OF MINUTES OF THE EXECUTIVE COMMITTEE.

Regular Meeting, July 24, 1902.—Engineers' Club of Philadelphia, 1122 Girard Street, Philadelphia, Pa. Present: Messrs. Dudley, Lesley, Christie, Colby and Marburg of the Executive Committee, and Mr. W. R. Webster on invitation.

The Secretary reported the receipt of 31 applications for membership, duly approved, one resignation, and the loss of one member by death—J. B. Johnson, who died on June 23, 1902, making the total membership 204.

In pursuance of resolutions at the Fifth Annual Meeting it was decided to create committees on "Protective Coatings for Iron and Steel" and on "Standard Specifications for Cement," and to postpone action relative to the appointment of a committee on "Standard Specifications for Paving and Building Brick."

At the invitation of President Tetmajer, nominations of American members were made for several international committees.

The Secretary was authorized to have a pamphlet on "Rules for Standard Tests of Materials Formulated by the German Association for Testing Materials" translated into English, at an expense of $25.

The President was authorized to appoint standing committees (*a*) on Finance (*b*) on Publication, (*c*) on Membership.

It was decided to issue the Proceedings henceforth in the form of annual volumes.

The Secretary submitted a set of proposed rules for the government of the Executive Committee, which were adopted in amended form.

Regular Meeting, October 4, 1902.—Engineers' Club of Philadelphia, 1122 Girard Street, Philadelphia, Pa. Present: Messrs. Lesley, Christie and Marburg of the Executive Committee.

A telegram was received from President Dudley stating that owing to the lateness of his train it would be impossible for him to reach the meeting.

In the absence of a quorum it was decided to hold an informal meeting, with the understanding that any action taken would be subject to the approval of the Executive Committee at its next meeting.

The Secretary reported the receipt of 24 applications for membership, duly approved.

The Secretary announced the appointments by the President on standing committees of the American Society and nominations on International Committees.

The Secretary quoted from a letter from President Tetmajer to the effect that the American Society for Testing Materials had been duly elected to membership as a body in the International Association for Testing Materials.

It was decided to subscribe the sum of $20 (100 francs) toward the general funds of the International Association.

The price of the Proceedings to non-members was fixed at three dollars ($3) and that of extra copies to members at one dollar ($1) per copy.

REGULAR MEETING, January 3, 1903.—Engineers' Club of Philadelphia, 1122 Girard Street, Philadelphia, Pa. Present: Messrs. Dudley, Lesley, Christie and Marburg.

The proceedings of the meeting held on October 4, 1902, in the absence of a quorum, were formally approved.

The Secretary reported the receipt of 36 applications for membership, duly approved, and one resignation, bringing the total membership to 263.

The report of the Auditing Committee was submitted, certifying to the correctness of the Treasurer's accounts up to December 31, 1902.

It was resolved to appoint American committees on "Standard Specifications for Cast Iron and Finished Castings" and on "Bitumen."

The Secretary reported the receipt of the following publications from President Tetmajer for distribution among the American members:

1. Revised By-Laws of the International Association.

2. Revised List of Technical Problems, Committees and Referees.

3. Minutes of Proceedings of Tenth Meeting of the International Council, Vienna, March 1, 2, 1902.

The Secretary stated that the Revised By-Laws had been reprinted in full in the pamphlet recently issued; that the Revised List of Technical Problems, etc., contained numerous errors, and that its contents in so far as it interested the American members had also been published in corrected form in the pamphlet; and that the translation of the Minutes of Council was so defective that President Tetmajer had agreed to its republication in America at the expense of the International Association. It was decided to accept this offer and not to distribute the other two publications.

The price of the Bulletins was fixed at ten cents (.10) each.

It was decided to continue the committee on "Heat Treatment of Iron and Steel" as at present constituted, to reorganize the committee on "Magnetic Properties of Iron and Steel," and to create a committee on "Standard Specifications for Paving and Building Brick."

The Secretary was instructed to send complimentary copies of Volume II. of the Proceedings to the members of the International Council.

REGULAR MEETING, April 4, 1903.—Engineers' Club of Philadelphia, 1122 Girard Street, Philadelphia, Pa. Present: Messrs. Dudley, Lesley, Christie and Marburg, members of the Executive Committee, and Mr. E. H. Martin as representative of Mr. McLeod.

The Secretary reported the receipt of 49 applications for membership, duly approved, and three resignations, making a total membership of 309.

The enlarged membership of the following committees was formally approved:

On Standard Specifications for Cement.

On Standard Specifications for Cast Iron and Finished Castings.

On Protective Coatings for Iron and Steel.

On Magnetic Testing of Iron and Steel.

On Bitumen.

It was decided to change the designation of the American branch of International Committee No. 1, in its enlarged form, to that of a committee on "Standard Specifications for Iron and Steel."

It was resolved to recommend to the Society at its next annual meeting: (1) That on all standing committees concerned with subjects involving commercial interests an equal numeric balance shall be preserved between engineers, scientists and representatives of consumers on the one hand, and manufacturers or their representatives on the other; (2) that the permanent chairmanship shall be vested in a member belonging to the former class, duly elected by the committee.

The President was empowered to authorize expenditures on the part of standing committees to an amount not exceeding twenty-five dollars ($25) for any single committee, between the quarterly sessions of the Executive Committee.

It was agreed to hold the Sixth Annual Meeting at Delaware Water Gap, Pa., on July 1, 2 and 3.

The arrangement of the program for the annual meeting was left with power to the President and Secretary.

It was decided to authorize an exchange of publications with other technical societies who might wish to take the initiative, and to allow a discount of 20 per cent. on all publications to libraries, publishers and book dealers.

The Secretary was instructed to notify delinquents in arrears for one year or more that unless their dues be paid by July 1 they would become subject to the provisions of the new By-Laws respecting delinquents.

The appointment of a nominating committee for prospective vacancies on the Executive Committee was left with power to the President.

SPECIAL MEETING, May 23, 1903.—Engineers' Club of Philadelphia, 1122 Girard Street, Philadelphia, Pa. Present: Messrs. Christie, Colby, McLeod and Marburg of the Executive Committee, and Mr. W. R. Webster on invitation.

The Committee on Program for the Sixth Annual Meeting submitted a provisional list of speakers and subjects, which was approved, and the committee continued to perfect arrangements for the meeting.

The Secretary announced the appointment by the President of Messrs. W. R. Webster, G. S. Webster and S. T. Wagner on the committee for nomination of officers, and that this committee had nominated Messrs. Albert Ladd Colby and John McLeod for membership on the Executive Committee for 1903–05.

It was resolved to recommend the adoption of the following amendment of the By-Laws: That Section 3, Article I., be designated Section 4, and that a new Section 3 be inserted, viz.: "Any member who subscribes annually the sum of fifty dollars ($50) toward the general funds of the Society shall be designated a Contributing Member, his rights and privileges as a member remaining unchanged."

In pursuance of an inquiry from President Tetmajer it was decided to furnish the Proceedings to members of the International Association at the regular price of three dollars ($3) per volume.

Attention was called to the desirability of giving due recognition to the English language in printing the Proceedings of the International Association, and it was agreed to bring this matter up for formal action at the Annual Meeting.

PREVIOUS PUBLICATIONS.

TABLE OF CONTENTS.

NOTE.—The Society, from its organization in 1898 till its incorporation under its present name in 1902, was designated the American Section of the International Association for Testing Materials. During this period twenty-eight (28) Bulletins were issued, which, collectively, constitute Volume I. of the Proceedings. In 1902 it was decided to publish the Proceedings in the form of annual volumes. Volume II, containing [illegible] pages, is the first volume of this new series. An abridged Table of Contents follows.

VOLUME I.

VOLUME II.

APPENDICES.

PRICE LIST.

Bulletins Nos. 1, 2 and 3 are out of print. The remaining publications may be obtained on application to the Secretary at the following prices: Bulletins Nos. 4 to 28, inclusive, ten cents (.10) each; Volume II., three dollars ($3), postage prepaid. Libraries, publishers and book-dealers are allowed a discount of 20 per cent.

OFFICERS

OF THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

PRESIDENT.

L. VON TETMAJER.

VICE-PRESIDENTS.

A. MARTENS, N. BELELUBSKI.

MEMBERS OF COUNCIL.

Every country having a membership of twenty or more in the Association is entitled to a representative on the Council.

Austria—F. BERGER.
Belgium—A. GREINER.
Denmark—J. HANNOVER.
England—W. C. UNWIN.
France—H. LE CHATELIER.
Germany—A. MARTENS.
Holland—L. BIENFAIT.
Hungary—C. VON BANOVITS.
Italy—J. BENETTI.
Norway—S. A. LUND.
Roumania—A. O. SALIGNY.
Russia—N. BELELUBSKI.
Spain—M. CANO Y DE LEON.
Sweden—A. WAHLBERG.
Switzerland—F. SCHUELE.
United States of America—CHARLES B. DUDLEY.

SECRETARY.

ERNEST REITLER,
Nordbahnstrasse 50, Vienna, II, Austria.

Communications for the International Association should be directed to the President, Professor L. von Tetmajer, Imperial Technical High School, Karlsplatz, Vienna, IV, Austria.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

BY-LAWS.

Adopted at the Buda-Pesth Congress, 1901.

SECTION 1. The Association shall be called "THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS."

SEC. 2. The objects of the Association are: the development and unification of standard methods of testing; the investigation of the technically important properties of the materials of construction and other materials of technical importance, and also the perfecting of apparatus used for this purpose.

These objects will be furthered:

1. By the Congresses and other meetings of the Association.
2. By the publication of an official Journal.
3. By any other means that may appear desirable.

SEC. 3. The funds necessary for carrying out the purposes mentioned in Section 2 will be raised by

1. The annual subscriptions of members.
2. Profits from the official Journal.
3. Other contributions.

SEC. 4. Any person may become a member upon being proposed by two members of the Association.

Official bodies and technical societies can be elected directly on their sending in their application for membership.

Applications for membership must be sent in writing to the President or to a member of the Council.

Resignations of membership must be sent in the same way.

SEC. 5. It is the duty of every member to further the interests of the Society to the best of his ability.

Every member is required to pay an annual subscription of at least 6 Mks. = 6 shillings = $1.50.*

The Council is authorized to increase the annual subscription in order to cover extraordinary expenses incurred in the interests of the Association.

* Subscriptions are to be paid to the duly appointed collectors in each country, the card of membership serving as a receipt. Subscriptions not paid by the first of July are collected through the post-office.

SEC. 6. Every member has the right to obtain the Journal of the Association, during the period for which his subscription has been paid, on paying the fixed reduced price.*

SEC. 7. The Association will hold a Congress, as a rule, every second year.

The arrangements for the Congresses will be discussed at general meetings and in meetings of the different sections.

Sections will be formed for the different groups of materials as may be considered necessary.

At present there are three sections:

I. Metals.

II. Natural and artificial building stones, cements and mortars.

III. Other materials of technical value.

Any special questions relating to the subjects of the different sections will be considered at sectional meetings.

The members assisting at the sectional debates, under the presidency of a member of the Council, will appoint the governing bodies of the different sections.

The results of the deliberations of the different sections must be communicated at a general meeting which will pass resolutions embodying the proposals of the sections.

Reports of Commissions, proposals of the Council and other matters to be laid before the Congress, will be printed in German, French and English, and will be sent (in the language preferred) to all members who have announced their intention of taking part in the Congress, within fourteen days before the meeting of the Congress, if possible.

The decisions of the Congress will be printed in all three languages and sent to all members of the Association.

SEC. 8. The Council of the Association will transact all necessary business connected with the Association.

The Council will consist of the President and the duly elected members.

Every country represented in the Association by at least twenty members has the right to propose one member as member of the Council.

The President will be elected by the Congress, the Council by the members belonging to the different countries.

* The reduced price has been fixed at 10 Mks. (= 10 shillings = $2.50). This sum may be sent in with the subscription. The yearly volume begins on January 1.

Till such election has taken place the former members of the Council remain in office.

The names of proposed new members of the Council have to be communicated to the President before each Congress.

The two Vice-Presidents will be elected by the Council from among its own members.

The Council is entitled to transact business when it has been duly called together according to rule and when the President or one of the Vice-Presidents is present.

Members of the Council may be re-elected.

If a member of the Council resigns during his term of office, the President shall immediately direct the election of a substitute by the members belonging to the country in question.

In the event of the death or resignation of the President, the Council will appoint one of its members to carry on the presidential duties till the next Congress.

The term of office of the Council lasts from one Congress till the next.

Sec. 9. The business of the Association will be attended to by the President, assisted by a paid Secretary.

The members of the Council will attend to the business of the Association in the country which they represent.

Sec. 10. The resolutions of the Congresses on technical questions merely serve to express the opinion of the majority. They are therefore in the form of recommendations and are in no way binding.

Sec. 11. The resolutions of the Congresses can only be carried if at least three-fourths of the recorded votes are in favor of them. Every member of the Association present, as well as every representative of official bodies and technical societies, has one vote.

The rights and duties of a member of the Association are not altered by the fact of his belonging at the same time to a national or other Association which Association is itself a member of the International Association.

Sec. 12. The technical problems to be considered by the Association will be decided upon by the Congresses and by the Council and will be duly referred to commissions or reporters appointed by the Council.

Sec. 13. The Council draws up its own regulations according to the By-Laws of the Association and to the needs which may from time to time present themselves.

Sec. 14. In the event of the Association being dissolved, any funds belonging to it will be handed over to the "International Red Cross Association."

THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

TECHNICAL PROBLEMS, COMMITTEES* AND REFEREES.
As constituted in August, 1903.

SECTION A.

METALS.

Problem 1.—On the basis of existing specifications, to seek methods and means for the introduction of international specifications for testing and inspecting iron and steel of all kinds. (Proposed at the Zurich Congress, 1895.)

Committee.

Chairman, A. Rieppel, Aeussere Cramer-Klettstrasse 12, Nuremburg, Germany.

Vice-Chairman, G. Alpherts, Koninginnegracht 66, Hague, Holland.

American Members, H. H. Campbell, James Christie, Carnegie Steel Company, represented by John McLeod: Franklin Institute, represented by Wm. H. Wahl, Paul Kreuzpointner, R. G. Moldenke, W. R. Webster, Walter Wood.

Problem 2.—To establish methods of inspection and testing for determining the uniformity of individual shipments of iron and steel. (Proposed at the Stockholm Congress, 1897.)

Committee.

Chairman, W. Ast, Nordbahnhof, Vienna, Austria.

Vice-Chairman, (office vacant).

American Members, Booth, Garrett and Blair, Thos. Gray, Gus. C. Henning, Paul Kreuzpointner, A. A. Stevenson, W. R. Webster, Albert Sauveur.

* The names of only the Chairman, the Vice-Chairman and American Members of International Committees are here given.

Problem 3.—On the properties of soft steel (Flusseisen) at abnormally low temperatures. (Proposed at the Zurich Congress, 1895.)
Referee (office vacant).

Problem 4.—Methods for testing welds and weldability. (Proposed at the Zurich Congress, 1895.)
Referee, R. Krohn, Gutehoffnungshuette, Sterkrade, Germany.

Problem 5.—Collection of data for establishing standard rules for piece tests, with special reference to axles, tires, springs, pipes, etc. (Proposed at the Zurich Congress, 1895.)

Committee.

Chairman, W. Rayl, Nordbahnstrasse 50, Vienna II, Austria.
Vice-Chairman, A. Sailler, Favoritenstrasse 20, Vienna IV, Austria.
American Members, M. H. Wickhorst, H. V. Wille.

Problem 6.—On the most practical methods of polishing and etching for the macroscopic study of iron and steel. (Proposed at the Zurich Congress, 1895.)
Referee, E. Heyn, Carmerstrasse 15, Charlottenburg, Germany.

Problem 25.—To establish uniform methods of testing cast iron and finished castings. (Proposed at the Buda Pesth Congress, 1901.)

Committee.

Chairman, C. Juengst, Kurfuerstendamm, 214 p. Charlottenburg, Germany.
Vice-Chairman, R. G. Moldenke, P. O. Box 432, New York, N. Y.
American Members, Alex. E. Outerbridge, Jr., Albert Sauveur, Thos. D. West.

Problem 26.—Tests with notched bars for ascertaining the relations between the different methods of testing and for fixing the numerical values representing the different properties of metals. (Proposed at the Buda-Pesth Congress, 1901.)
Referee, Ed. Sauvage, rue Eugène Flachat 14, Paris, France.

Problem 27.—Ball-pressure tests for ascertaining the relations between the different methods of testing and for fixing the numerical values representing the different properties of metals. (Proposed at the Buda-Pesth Congress, 1901.)
Referee, A. Wahlberg, Techn. Hochschule, Stockholm, Sweden.

Problem 28.—The consideration of the magnetic and electric properties of materials in connection with their mechanical testing. (Proposed at the Buda-Pesth Congress, 1901.)

Referees, K. Hochenegg, Techn. Hochschule, Karlsplatz, Vienna IV, Austria; M. von Hoor Tempik, Kgl. techn. Hochschule, Buda-Pesth, Hungary.

SECTION B.

NATURAL AND ARTIFICIAL BUILDING STONES AND THEIR CEMENTS.

Problem 7.—On the relation of chemical composition to the weathering qualities of building stones; the influence of smoke, especially sulphurous acid on building stones; the weathering qualities of roofing slates. (Proposed at the Zurich Congress, 1895.)

Committee.

Chairman, A. Hanisch, Schellinggasse 13, Vienna I, Austria.
Vice-Chairman, P. Larivière, Quai Jemmapes 170, Paris, France.
American Members, J. F. Kemp, Mansfield Merriman.

Problem 9.—On rapid methods for determining the strength of hydraulic cements. (Proposed at the Zurich Congress, 1895.)

Committee.

Chairman, F. Berger, Rathhaus, Vienna I, Austria.
Vice-Chairman, L. von Tetmajer, Techn. Hochschule, Karlsplatz, Vienna IV, Austria.
American Members, W. W. Maclay, Chas. F. McKenna.

Problem 10.—To digest and evaluate the resolutions of the conferences of 1884-1893 concerning the adhesive qualities of hydraulic cements.

Referee, R. Féret, Boulogne-sur-Mer, France.

Problem 11.—To establish methods for testing puzzolanas with the object of determining their value for mortars. (Proposed at the Zurich Congress, 1895.)

Committee.

Chairman, G. Herfeldt, Andernach, Germany.
Vice-Chairman, C. Segré, Ancona, Italy.
American Members, A. Lundteigen.

Problem 12.—Investigation on the behavior of cements as to time of setting and on the best method for determining the beginning and the duration of the process of setting. (Proposed at the Zurich Congress, 1895; enlarged in conformity with the resolution of the Buda-Pesth Congress, 1901.)

Committee.

Chairman, E. Candlot, rue d'Edimbourg 18, Paris, France.
Vice-Chairman, N. Lamine, Zabalkansky 9, St. Petersburg, Russia.
American Members, Spencer B. Newberry, Clifford Richardson.

Problem 13.—On the normal consistency of cement mortars for test specimens. (Proposed at the Zurich Congress, 1895.)

Committee.

Chairman, A. Greil, Rathhaus, Vienna I, Austria.
Vice-Chairman, L. von Tetmajer, Techn. Hochschule, Karlsplatz, Vienna IV, Austria.
American Member, R. L. Humphrey.

Problem 14.—On the influence of sulphurous acid on artificial stones and mortars. (Proposed at the Stockholm Congress, 1897.)
Referee (office vacant).

Problem 15.—On the action of sulphuretted hydrogen dissolved in water or in a gaseous condition upon different kinds of mortar. (Proposed at the Stockholm Congress, 1897.) (To be treated as Problem 14, and eventually added to it.)
Referee (office vacant).

Problem 29.—Determination of the liter weight of cement. The strength of neat hydraulic cements. Determination of a standard sand. (Proposed at the Buda-Pesth Congress, 1901.)
Referees, N. Belelubski, rue Serpuchowskaja 4, St. Petersburg, Russia; F. Schuele, Edig. Polytechnikum, Zurich, Switzerland.

Problem 30.—Determination of the simplest method for the separation of the finest particles in Portland cement by liquid and air processes. (Proposed at the Buda-Pesth Congress, 1901.)
Referee, M. Gary, Kgl. mech.-techn. Versuchsanstalt, Charlottenburg, Germany.

Problem 31.—On the behavior of cements in sea water. (Proposed at the Buda-Pesth Congress, 1901.)
Referee, H. Le Chatelier, Place du College de France 9, Paris, France.

Problem 32.—On accelerated tests of the constancy of volume of cements. (Proposed at the Zurich Congress, 1895.)

Committee.

Chairman, Bertram Blount, Broadway Westminster, London, S. W., England.
Vice-Chairman (office vacant).
American Members, R. W. Lesley, Spencer B. Newberry.

Problem 33.—On the influence of the proportion of water and sand on the strength of Roman and other cements. (Proposed at the Buda-Pesth Congress, 1901.)
Referee, The Hungarian Society for Testing Materials, Buda-Pesth, Hungary.

SECTION C.

OTHER MATERIALS.

Problem 17.—On methods of testing tile pipe. (Proposed at the Stockholm Congress, 1897.)
Referee, M. Gary, Kgl. mech.-techn. Versuchsanstalt, Charlottenburg, Germany.

Problem 18.—On the methods of testing the protective power of paints used on metallic structures. (Proposed at the Zurich Congress, 1895.)
Referees, Albert Grittner, Köbanyai ut 30, Buda-Pesth, Hungary; E. Ebert, Centralbahnhof, Munich, Germany.

Problem 19.—On uniform methods for testing lubricants. (Proposed at the Zurich Congress, 1895.)
Referee, N. Petroff, Zagorodny 70, St. Petersburg, Russia.

Problem 23.—On uniform methods for compression tests of wood.

Committee.

Chairman, Prof. A. Schwappach, Eberswalde, Germany.
Vice-Chairman, A. Wykander, Goeteborg, Sweden.
American Member, Filibert Roth.

Problem 35.—Study of the methods of testing caoutchouc. (Proposed at the Buda-Pesth Congress, 1901.)

Committee.

Chairman, E. Camerman, rue Philippe Le Bon 73, Brussels, Belgium.
Vice-Chairman (office vacant).
American Member, R. G. Pearson.

Section D.

MISCELLANEOUS SUBJECTS.

Problem 22.—Considering that the resolutions formed by the International Conferences of Munich, Dresden, Berlin, Vienna and Zurich, for the purpose of attaining unity in the methods of testing materials, and the report of the Committee of the American Society of Mechanical Engineers do not agree in many points with the decisions arrived at by the French Commission, it is proposed that the Council appoint a commission which shall prepare a report upon these differences, and proposals for ways and means of abolishing them.

Committee.

Chairman, N. Belelubsky, rue Serpouchowskaya 4, St. Petersburg, Russia.
Vice-Chairmen, A. Martens, Kgl. mech.-techn. Versuchsanstalt, Charlottenburg, Germany; E. Sauvage, l'Ecole des Mines, Paris, France.
American Members, Albert Ladd Colby, Gus. C. Henning, R. G. Moldenke, George F. Swain, George S. Webster, W. R. Webster, Walter Wood.

Problem 24.—On uniform nomenclature of iron and steel. (Resolution of Council, February 3, 1901.)

Committee.

Chairman, H. M. Howe, 27 West Seventy-third street, New York, N. Y.
Vice-Chairmen, L. Lévy, rue de la Rochefoucauld 19, Paris, France; D. Tschernoff, rue Pessatschenaia 25, St. Petersburg, Russia.
Secretary, Albert Sauveur, 446 Tremont Street, Boston, Mass.
American Member, H. H. Campbell.

Problem 34.—Fixing a uniform definition and nomenclature of the bitumens. (Proposed at the Buda-Pesth Congress, 1901.)

Committee.

Chairman, G. Lunge, Eidg. Polytechnikum, Zurich, Switzerland.
Vice-Chairman, Jenoe Kovács, Tataros (Post Mezoe Telegd), Hungary.
American Members, A. W. Dow, Clifford Richardson.

TECHNOLEXICON.

NOTE.—The Executive Committee has directed that space be given to the following communication, as a matter of general interest to the members of the Society.

The universal technical dictionary for translation purposes, in English, German, and French, the compilation of which was begun in 1901 under the auspices of the SOCIETY OF GERMAN ENGINEERS, has received help up to the present time from 363 technical societies at home and abroad: 51 of these are English, American, South African, etc.; 274 German, Austrian, and German-Swiss; and 38 French, Belgian, and French-Swiss societies. Of firms and individual collaborators 2573 have promised contributions.

The excerption of texts in one, two, or three languages (handbooks, pamphlets, business letters, catalogues, price-lists, etc.) and of the existing dictionaries has yielded 1,920,000 word-cards so far. To these will be added within the next two years (by the middle of 1906) the hundred thousands of word-cards that will form the result of the original contributions—those already sent in and those still expected—of the 2573 collaborators at home and abroad, when the editors in Berlin have finished them for the press.

Specially made handy note-books had been placed at the disposal of the collaborators to write their collections in, of which 317 have come in filled so far.

All the outstanding contributions will be called in *by Easter of this year*, 1904. The collaborators are therefore requested to close their note-books or other contributions—unless a later term has been especially arranged with the Editor-in-Chief—by the end of March and to forward them to the address given below. As the printing of the Technolexicon is to begin in the middle of

1906. delayed contributions can be made use of in exceptional cases only up to that time.

The Editor-in-Chief will be pleased to give any further information wanted.

Address:

TECHNOLEXICON,

DR. HUBERT JANSEN,

Dorotheenstrasse 49, Berlin (NW. 7).

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AUTHOR INDEX.

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